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TABLE OF CONTENTS

Page

Kidney Disease in Brook Trout and Its Treatment
-- S. F. Snieszko and Philip J. Griffin 3

Results of Planting Catchable-Size Brown Trout, Salmo trutta fario L., in a Stream With Poor Natural Reproduction
-- John G. Hale and Lloyd L. Smith, Jr. 14

The Hatching of Chinook Salmon Eggs Under Simulated Stream Conditions
-- Jack M. Shelton 20

An Injection Method for Marking Crayfish
-- Keith V. Slack 36

A Simple Trap Method for Rescuing Fingerling Salmonids
-- J. B. Kimsey and Gerald R. Holman 39

A Modification of the Kemmerer Water Bottle for Sampling Shallow Waters
-- Charles R. Walker 41

Dividends From Research

The Birth of a Fishery
-- Donald L. McKernan 42

Warm-Water Fishing Regulations
-- Kenneth E. Christensen 43

The Walleye Problem in Green Bay
-- Ralph Hile 44

Item

Bentonite and Largemouth Bass Eggs 19

North American Fish Policy 45

Comment 35

Page

Review

Fertilizers in Fishponds

-- C. H. Mortimer and C. F. Hickling 47

Clearing House 48

KIDNEY DISEASE IN BROOK TROUT AND ITS TREATMENT

S. F. Snieszko and Philip J. Griffin
with the assistance of
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and
Fish-Cultural Station, Berlin, New Hampshire

OUTBREAKS OF KIDNEY DISEASE among our salmonid fishes have been described from the States that are near the Atlantic and the Pacific coasts of the United States. So far, this disease has not been reported from inland States. Similar or identical diseases have been discovered in other countries. The literature pertaining to the research on kidney disease has been reviewed recently by Earp, Ellis, and Ordal (1953) and in the "Symposium on Fish Diseases" (1954).

During the past several years this disease has caused severe losses in brook trout (Salvelinus fontinalis) of various age groups at the Federal hatchery at Berlin, New Hampshire. Recently it has also caused losses among brook trout, brown trout (Salmo trutta), and rainbow trout (Salmo gairdnerii) at the Federal hatchery at Cortland, New York.

Because there is some variation in the descriptions of the syndromes of this disease as described by various authors, all the signs reported are summarized here.

External symptoms. --Abdomen distended, exophthalmos, and blisters. The blisters occur most frequently on the sides and are filled with clear amber or turbid fluid containing tissue cells and the pathogens.

Musculature. --Abscesses filled with nearly colorless or turbid fluid.

Internal Organs. --Changes in the kidneys are most characteristic. Kidneys are swollen and show small to large gray-white necrotic areas. In advanced stages of this disease the whole kidney is greatly enlarged and necrotic. Similar necrotic areas may occur in the liver and spleen. The anal region of the intestine may be swollen, and the intestine may be filled with a yellow purulent fluid. There is an accumulation of light, amber, semitransparent fluid--or of an opaque red fluid--in the abdominal cavity. Sometimes this fluid exerts considerable pressure on the abdominal wall. This fluid usually contains blood cells and small gram-positive micro-organisms. Sometimes the spleen and heart are covered with opaque false membranes which impart a white appearance. Petechiae may appear in the skin and peritoneum.

Frequently an additional lesion is observed during macroscopical examination of the visceral organs. In early stages, lesions appear as small papillae projecting from the outer walls of the stomach or esophagus. In more advanced stages, the intestines and pyloric caeca may be completely encased in a proliferating mass of glistening white tissue which may easily be confused with the mature testis.

Histologically the diseased tissue is similar to the granuloma associated with

the various mycoses and tuberculosis of mammals. It is systemic in distribution; and small miliary tubercles may be seen in the gills, liver, spleen, kidney, eyes, and musculature, as well as in the anterior parts of the gastrointestinal tract. The large masses surrounding the visceral organs are composed of typical well-defined tubercles. Giant cells are common. Microscopic abscesses are frequently seen. A small funguslike organism is always associated with the lesions. The organism is a round, budding, double-walled, yeastlike form which bears some resemblance to the blastomycetes.[1/] The possibility that this fungus may belong to the genus Ichthyosporidium (Ichthyophonus), quite common in the European trout hatcheries (Schäperclaus 1941), will be taken under consideration in subsequent investigations.

It is not known at this time whether the granulomatous lesion has any connection with kidney disease, or whether the presence of the lesion is coincidental in susceptible trout.

All of these symptoms never occur in all outbreaks or in all infected fishes. Very frequently the only apparent symptom is the presence of gray-white spots in the kidneys. Preliminary observations seem to indicate that the syndromes in brown trout and in rainbow trout may differ from the syndromes observed in brook trout.

Pathogens. -- Small gram-positive and nonmotile rod-shaped micro-organisms are present in the lesions. These micro-organisms have been isolated by using fresh tissues or chick embryos, and subcultures have been made in media containing coagulated hen's eggs (Earp, Ellis, and Ordal, 1953). Infection experiments have indicated that this micro-organism most likely is the etiological agent of the kidney disease.

1/ Histopathological investigations of the diseased fish and the photomicrographs presented with this paper were made by Dr. E. M. Wood of the U. S. Fish and Wildlife Service, Cook, Washington.

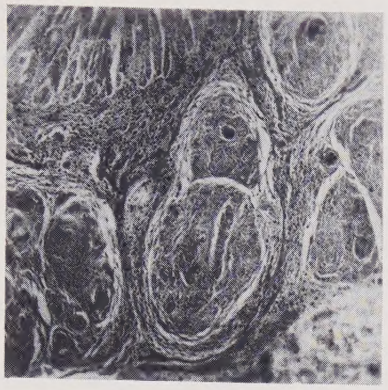
Observations and Treatment Experiments at the Berlin Station

In June 1953, 150 brook trout selected at random from various age groups and from various parts of the hatchery were examined. Some had been dead for less than 24 hours, others were alive but obviously ill, and still others were apparently healthy. Of the last group, 116 evidenced moderate to severe kidney lesions. The posterior portion of the kidney appeared to be the most frequent site of involvement. In most of these trout, the intestines contained no food and inflammation was extensive. Practically without exception, the anal region appeared swollen and a yellowish purulent fluid could easily be expressed from the vent by exerting moderate pressure about the involved region. Not infrequently, small ulcerative areas were noted on the surface of the belly. The ulcers did not penetrate through the musculature to the body cavity. As these small ulcers could also have been early symptoms of ulcer disease, bacteriological examination was made. Results were negative, for Hemophilus piscium was not isolated.

From representatives of the various groups, 55 kidney-lesion smears were prepared for microscopic examination. In every instance in which gross kidney lesions were present, minute gram-positive diplobacilloid micro-organisms were found intracellularly and extracellularly. Diseased fish were found in the

Opposite Page

FIGURE 1.--Mycotic granuloma. Gastric caecum at upper left. All other tissue is aberrant. X 60.
FIGURE 2.--Miliary tubercles in visceral fat surrounded by normal pancreatic tissue. X 100.
FIGURE 3.--Mycotic organism in visceral lesion. Mallory's fungi stain. X 200.
FIGURE 4.--Figure 3, X 400.
FIGURE 5.--Granuloma in intestinal wall. X 200.
FIGURE 6.--Diplobacillus in tissue section. Gram stain. X 2000.



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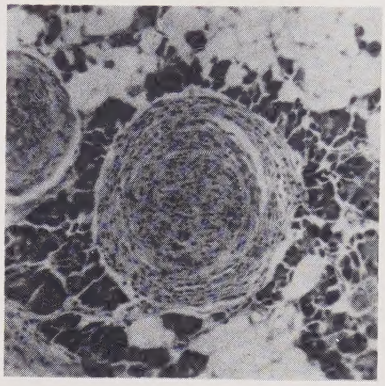

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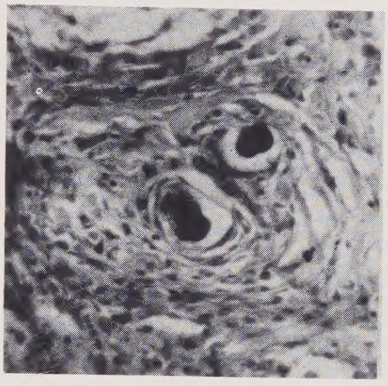

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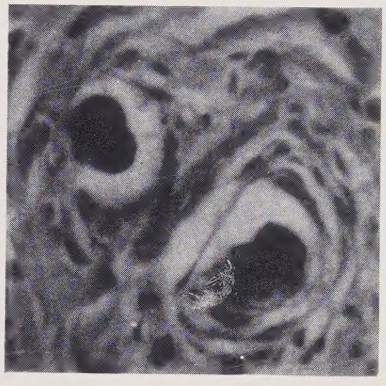

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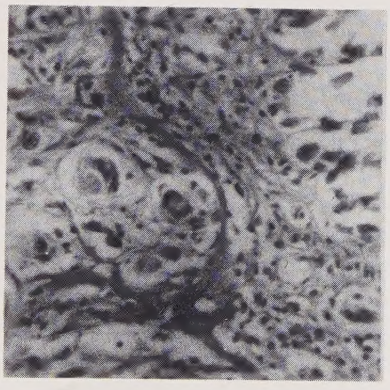

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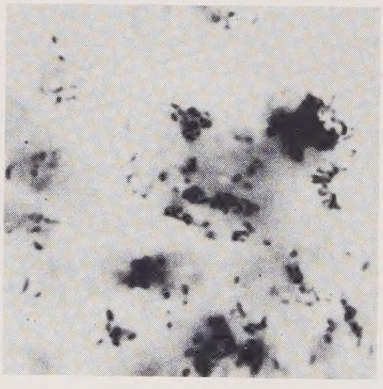

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For legends, see page 4.

stream supplying water to the hatchery and in various ponds and raceways.

The observations reported by Rucker, Bernier, Whipple, and Burrows (1951) and by Earp, Ellis, and Ordal (1953) have shown that sulfonamides in the form of sulfadiazine, sulfamerazine, and sulfamethazine were used for the treatment of this disease, with the varying degree of success depending on the dosage, length of treatment, and the species of diseased salmon.

For the treatment experiments at the Berlin Station, yearling brook trout were selected. They were mixed well and then divided evenly into 8 units. Each unit received 150 pounds of trout. On the basis of random sampling, it was estimated that there were about 1,500 trout per unit. The treatments were distributed in one randomized block in the following manner (dosages expressed in grams of drug per 100 pounds of fish per day):

Units	Treatment
A,B	Controls.
C,D	Sulfamerazine, 12 grams for 3 days, followed by 8 grams for 46 days.
E,F	Sulfanilamide, 12 grams for 3 days, followed by sulfamerazine, 8 grams for 46 days.
G,H	Sulfadiazine, 12 grams for 10 days, followed by 6 grams for 39 days.

Drugs were mixed with the required amount of food, and the fish were fed once daily. Treatments and the recording of mortalities were started on June 17 (table 1).

The experiment, originally scheduled for 21 days, was extended to cover a total of 12 weeks in order to obtain more complete information. At the end of each week, the mortality and daily temperature records were sent to the Microbiological Laboratory at Leetown. During the first 7 weeks, 6 fish (3 dead and 3 living) from each test unit were placed in formalin and sent to the Leetown laboratory for examination. An additional group was sent at the end of the experiment.

The various sulfonamides were administered at the prescribed rate for 7 full weeks, at the end of which time the drugs were discontinued in units C, F, G, and H. Sulfamerazine was administered continually to the fish in units D and E at the rate of 8 grams per 100 pounds of fish per day for the remainder of the experiment.

At the end of the first week of treatment, the total mortalities were slightly higher in the treated units than in the controls. Exceptionally high mortalities occurred during the first week in units E and F. This was due to the administration of sulfanilamide for the first 3 days. The fish in units E and F refused food on the third day, and the combined mortalities in these units totaled 144 on the third day and 189 on the fourth day. In the controls, mortality for corresponding days totaled 41. From the fifth day on, the mortalities in units E and F were essentially comparable to those in units C and D (sulfamerazine units). Sulfanilamide was tried because of its rapid absorption by brook trout (Snieszko and Friddle 1951). On account of its toxicity to trout, sulfanilamide was given only during the first 3 days of treatment. It was thought, however, that sulfanilamide, owing to its rapid absorption, could be very effective even if given for a short time.

The data presented in table 1 show that in 3 weeks the mortalities in the treated units became fewer. Essentially the results were very similar in all groups, but the data from the sulfamerazine-treated units appear slightly better. The fact that the mortalities in the control units also declined sharply indicated that the epizootic had reached its peak before the experiment was started. Therefore, it should be assumed that the therapeutic effect of sulfonamides was less apparent than it would have been if the treatments had been started earlier. No significant difference in the mortalities was noted in those units which continued to receive sulfamerazine after the seventh week. In contrast to the results in the treated units, the number of mortalities in the control units started slowly to increase after the seventh week.

Data obtained previously at the Leetown Station (Gutsell and Snieszko 1949) indicated that prolonged treatments with sulfamerazine caused a slight reduction in the growth rate of the treated brook trout. In the Berlin experiment no such effect was apparent (table 1).

During the first 2 weeks, large numbers of typical micro-organisms could be found both extracellularly and intracellularly in material taken from the kidney. In the fourth week, extracellular micro-organisms predominated, especially in the treated groups. Of considerable interest was the definite change in morphology, from the typically small to larger diplobacilli. In the fifth week, examination of the controls revealed typical kidney-disease organisms, but a few aberrant forms were also seen. In the treated groups, decided alterations in the size and shape of these micro-organisms had occurred. There were larger diplobacilli, elongated forms (some beaded or banded), and many background "ghosts" which were faintly gram-positive and appeared diphtheroid. By the end of the sixth week, the controls and fish which died in the treated lots still had gross lesions, but only an occasional fish was found to contain typical kidney-disease micro-organisms.

The weekly shipments of specimens from Berlin to the Leetown Station were discontinued at the end of the 7th week, but a final lot was collected at the end of the 12th week. A most unexpected observation was made; namely, that although specimens from all units evidenced gross

TABLE 1.--Weekly mortalities (percentages) among yearling brook trout treated for the kidney disease at the Federal fish hatchery at Berlin, New Hampshire

Weekly periods, June 17 to September 8, 1953	Average temperature of water, °F.	Mortalities (percentages) in units-- Held as Controls		Receiving treatments with-- Sulfamerazine		Sulfanilamide followed by Sulfamerazine		Sulfadiazine	
		A	B	C	D	E	F	G	H
1	56.0	6.7	6.1	8.8	9.8	1/16.0	1/16.8	7.5	8.0
2	----	4.9	4.5	3.1	3.9	3.6	5.5	2.6	3.2
3	58.0	4.1	4.3	1.1	.8	1.3	1.5	1.6	1.9
4	55.5	2.5	2.0	.8	.6	.9	.9	1.2	.9
5	61.0	2.3	2.5	1.1	.5	.8	.6	1.6	1.5
6	58.0	1.2	.9	.1	.1	.3	.3	.8	.7
7	54.5	.9	1.9	2/.5	.5	.6	2/.5	2/.7	2/1.0
8	55.0	1.7	1.7	2/.0	.2	.1	2/.2	2/.9	2/.3
9	57.0	1.6	2.3	.2	.3	.7	.2	.3	.5
10	54.0	1.6	2.2	.5	.4	.2	.3	.2	.6
11	62.0	2.7	3.3	.6	.4	.5	.5	2.0	1.0
12	61.0	1.3	1.6	1.0	.1	.7	1.1	.5	1.0
Initial number of trout 3/		1,446	1,494	1,560	1,380	1,459	1,518	1,475	1,488
Total mortalities:									
Number		411	429	251	252	356	391	277	286
Percent		28	29	16	18	24	26	19	19
Average increase in weight per fish (percent)		89	97	76	89	100	94	92	89

1/ About half of these mortalities were most likely caused by the toxic effect of sulfanilamide on fish having advanced kidney damage caused by the kidney disease.

2/ Treatment was discontinued after 7 weeks.

3/ As calculated from the total mortalities and the number of fish left at the end of the experiment.

kidney lesions, in no instance could typical or atypical kidney-disease microorganisms be seen in any of the slides that were made from the kidney. This may be related to seasonal outbreaks of kidney disease at the Berlin Station. The losses due to this disease start in April or May, reach a peak in June, and gradually subside during the summer.[2/]

Laboratory Experiments on the Chemotherapy of Kidney Disease at the Leetown Station

Kidney disease considerably affects the production of brook trout at the Berlin and other eastern fish hatcheries. The field test on the treatment of this disease at the Berlin hatchery gave encouraging results. Therefore, additional investigations on the efficacy of treatment with some sulfonamides and antibiotics were made under controlled laboratory conditions at the Leetown Station.

Sulfamerazine, sulfadiazine, a mixture of sulfamerazine and sulfathiazole, and Gantrisin[3/] (3, 4 - Dimethyl - 5 - sulfanilamido-isoxazole) were selected from the sulfonamides. Sulfamerazine and sulfadiazine gave promising results at Berlin. Sulfathiazole gave remarkably good results in the treatment of furunculosis (Snieszko, Gutsell, and Friddle 1950), despite the relatively low tissue concentration as compared with that produced by oral administration of sulfamerazine (Snieszko and Friddle 1951). As sulfathiazole is also effective against gram-positive bacteria, it was possible that the drug could be useful in the treatment of kidney disease. Gantrisin, though given to chicks continuously for 6 weeks, neither showed toxic effects nor retarded their growth (Tabenkin, Cooperman, Drucker, and Jenkins, 1953). If Gantrisin proved to be therapeutically effective but nontoxic to brook trout, this drug would be superior to sulfamerazine. High levels of the latter retarded the growth of brook trout and completely arrested growth in brown trout (Gutsell and Snieszko 1949).

Terramycin, chloramphenicol, and aureomycin were selected from many antibiotics because these three have a wide antibacterial spectrum, may be given orally, and can be purchased in a semi-purified form at a cost which makes their use less prohibitive in fish culture.

The experiment was started early in July with fingerling brook trout that had an average weight of 12 grams. Fish were distributed into experimental troughs in a random manner. In an attempt to introduce kidney disease, 10 trout that had been infected with the disease by means of intramuscular or intraperitoneal injection

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[2/] From a letter written by Mr. Delisle on June 21, 1954:

"In commenting on the kidney disease situation thus far this season, ... the incidence of the disease has coincided to a large extent with your findings, as noted in this manuscript, in that the disease appears to be at its peak during the early spring months. The highest percentage of mortality so far this year has been during the period from April 15 to May 28. It first started on the brood stock lots of two-, three-, and four-year-old fish--on or about April 15. The yearling lots of fish were affected somewhat later--on or about May 12.

"The rate of mortality so far this year on the brood stock lots and the yearlings has been approximately as follows:

Brood Fish			
Number on hand:	April 1 -------	10,957	
	May 1 ---------	10,367	
	June 1 --------	10,084	
Loss:	April -----	590	(5.3 percent)
	May -------	283	(2.7 percent)
	June (to the 20th, inc.)	104	(1.0 percent)
Yearlings			
Number on hand:	April 1 ------	392,000	
	May 1 --------	345,000	
	June 1 -------	216,000	
Loss:	April -----	4,680	(1.2 percent)
	May -------	15,486	(4.5 percent)
	June (to the 20th, inc.)	3,641	(1.7 percent)

[3/] Registered trade-mark of Hoffmann-LaRoche, Inc.

were added to each trough. As the disease was not transmitted by the inoculated trout, 3 weeks later the fish were fed for 1 day a diet strongly enriched with ground brook trout that had just died or that had been about to die from kidney disease. Again during a month of observation there was no indication that infection by feeding was satisfactory. Therefore, fish were redistributed so that there were 100 trout per trough. Fifty of them were marked by clipping one pectoral fin and inoculated by parenteral introduction of a freshly prepared suspension from trout with kidney disease in an advanced stage. In anticipation of the rapid progress of the disease, treatments were started 2 days in advance of this inoculation. The remaining 50 trout per trough were not infected by inoculation; thus they still could be utilized in this experiment if the earlier attempts at infection by contact and feeding should become successful, even though the effects were delayed.

Sulfonamides were given at a rate of 200 milligrams (9 grams per 100 pounds) and antibiotics at a rate of 75 milligrams (3.4 grams per 100 pounds) per kilogram of fish per day. Sulfamerazine and sulfathiazole were mixed in equal parts, and this mixture was given at the same rate as the other three sulfonamides. All drugs were mixed with food composed of beef liver and spleens with a dry mixture containing cottonseed meal (25 parts), fish meal (50 parts), wheat middlings (25 parts), and salt (4 parts). To obtain food of right consistency and of good binding, 2 parts of meat were used for 1 part of the dry mix. The feeding rate was 7 percent of the trout weight per day. The fish were fed twice daily. The water temperature was 12.5° C. (54° F.), and the treatment was continued for 45 days.

The results of the experiment are presented in table 2. All sulfonamides arrested the disease; of the antibiotics, chloramphenicol delayed the progress of the infection. The advance of the disease was rapid in the controls and in the lots treated with terramycin and aureomycin. The fish infected by intramuscular injection developed large necrotic lesions at the point of injection, and a generalized infection developed in those fish that had received intraperitoneal injections. The treatment was continued for 45 days in order to find out whether sulfonamides arrested the disease or only slowed its progress as did chloramphenicol.

As Rucker, Bernier, Whipple, and Burrows (1951) and Earp, Ellis, and Ordal (1953) found that sulfonamide therapy arrested but did not cure kidney disease in salmon, all lots of trout treated with sulfonamides were held under observation for 70 days after the end of treatment. The disease reappeared within 40 to 50 days (table 3). In the trout that received intramuscular injections, small lesions appeared at the point of injection soon after inoculation. In control trout, the lesions increased in size until the fish died. In the treated trout, the lesions healed but reappeared after the treatment was discontinued.

These experiments have shown that sulfonamides temporarily arrested the progress of kidney disease in fingerling brook trout. The degree of suppression of the disease was about the same with all the tested sulfonamides, but the results with sulfamerazine and Gantrisin were most favorable. Since Gantrisin had the slightest growth-retarding effect (table 2), it may be the drug of choice for the treatment of kidney disease in brook trout. The degree of retardation of the growth[4/] of trout treated with Gantrisin and sulfamerazine was not so great as one might conclude from the figures (table 2). The reason for this was that in the lots suffering higher losses, food was available in

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[4/] The purpose of these experiments was to determine the therapeutic value of some drugs for the treatment of kidney disease, not the effect of these drugs on the growth rate of normal brook trout. The quantities of the diets were not adjusted frequently enough; therefore the growth data should be considered only as showing trends rather than as quantitatively valid data. Results of nutritional experiments will be reported separately.

TABLE 2.--Mortalities among fingerling brook trout treated for the kidney disease with sulfonamides and antibiotics, Microbiological Laboratory, Leetown, West Virginia

Time periods, in days, from August 24 to October 7, 1953	Mortalities in units-- Held as Controls		Receiving treatment with-- Sulfamerazine		Gantrisin[1]		Sulfadiazine	
	A	B	A	B	A	B	A	B
1 to 18	1	1	1	---	---	---	1	---
19 to 23	5	7	---	---	---	---	---	1
24 to 28	25	13	---	---	---	---	---	1
29 to 33	12	13	---	---	1	---	1	---
34 to 38	3	6	---	---	---	---	---	1
39 to 45	4	4	---	---	---	---	---	1
Totals	50	44	1	---	1	---	2	4
Mortalities (percentages) among the 50 inoculated trout	100	88	2	---	2	---	4	8
Initial weight per fish[2]	19	20	18	19	19	20	16	18
Final weight per fish[2]	41	39	27	28	33	34	19	21
Weight gain, percentage[2]	116	95	50	47	74	70	19	17

Time periods, in days, from August 24 to October 7, 1953	Mortalities in units-- Receiving treatment with-- Sulfamerazine and Sulfathiazole		Chloramphenicol		Terramycin		Aureomycin[3]	
	A	B	A	B	A	B	A	B
1 to 18	---	1	1	1	2	---	1	---
19 to 23	2	---	---	---	1	1	4	2
24 to 28	---	---	---	---	6	2	12	7
29 to 33	---	---	---	1	9	9	15	14
34 to 38	---	---	1	4	9	6	9	9
39 to 45	---	1	2	3	6	10	5	2
Totals	2	2	4	9	35	28	46	33
Mortalities (percentages) among the 50 inoculated trout	4	4	8	18	70	56	92	66
Initial weight per fish[2]	18	18	20	18	18	20	20	21
Final weight per fish[2]	21	22	34	35	39	38	41	39
Weight gain, percentage[2]	17	22	70	94	117	90	105	86

[1] Gantrisin substance, Lot No. 611-613 furnished free of charge by Hoffmann-La Roche, Inc., Nutley, New Jersey.

[2] All figures are given as whole numbers, as differences in decimals are not significant.

[3] Calcium aureomycin, Lot No. 7-8664 furnished free of charge by the Lederle Laboratories Division, American Cyanamid Company, New York, New York.

increasing quantities from about the third week to the end of the treatment period. This may explain the somewhat disproportionate gain in weight among trout in the lots treated with terramycin, aureomycin, and the controls. On the other hand, the retardation of growth in the lots treated with sulfadiazine and the sulfamerazine-sulfathiazole mixture was so considerable that prolonged use of these drugs should not be recommended for the treatment of brook trout.

Discussion and Recommendations for Treatment

Kidney disease in brook trout in the eastern United States is probably identical with a disease described for salmon in the West (Rucker, Bernier, Whipple, and Burrows, 1951; Earp, Ellis, and Ordal, 1953). It is also probable that "salmon poisoning" in dogs and foxes is caused by the same micro-organism. According to Cordy and Gorham (1950), it belongs to the family Chlamydozoaceae of the order Rickettsiales. There are, however, some differences in the ease with which this pathogen is isolated from dogs and salmon, as well as in the response to the treatment with antibiotics. Aureomycin was very effective in the treatment of salmon poisoning in dogs (Cordy and Gorham 1951), but it failed in the therapy of kidney disease in brook trout. There is, however, some reason to suspect that the failure of aureomycin in the therapy of bacterial fish diseases may be due, at least in part, to the existence of some specific conditions in fishes, conditions which render ineffective the therapy with this antibiotic (Snieszko, Griffin, and Friddle, 1952).

Data on the treatment of kidney disease presented by Earp, Ellis, and Ordal (1953) were collected from many case histories and from several experiments conducted on sockeye (blueback) salmon (Oncorhynchus nerka) and coho (silver) salmon (O. kisutch). Most of the observations on chemotherapy reported by these authors were conducted in large ponds without facilities for rigid experimentation. The authors tested several sulfonamides at various dosage rates. The durations of treatments were changed from test to test. The experiments were further complicated by use of two species of salmon of various age groups. Therefore, the results that are reported by those authors must be considered exploratory until further experiments permit selection of the least toxic and most effective sulfonamide.

The results of the experiments that have been described by Rucker, Bernier, Whipple, and Burrows (1951), by Earp, Ellis, and Ordal (1953), and in this paper indicate that the drugs of greatest promise are Gantrisin, sulfamerazine, sulfamethazine, and sulfadiazine. The last-named one is apparently toxic to coho salmon and arrests the growth of brook trout, whereas the drug is effective and not toxic in the

TABLE 3.--Mortalities among fingerling brook trout during post-treatment observation time /This is a continuation of table 2./

Time periods, in days, from October 8 to December 16, 1953	Mortalities in units treated with--							
	Sulfamerazine		Gantrisin		Sulfadiazine		Sulfamerazine and Sulfathiazole	
	A	B	A	B	A	B	A	B
1 to 12	-----	-----	---	---	-----	-----	-----	-----
13 to 22	-----	-----	---	---	-----	1	1	-----
23 to 32	-----	-----	---	---	-----	-----	-----	-----
33 to 42	-----	-----	---	---	1	-----	1	-----
43 to 52	-----	2	11	9	2	1	5	-----
53 to 62	8	11	20	15	19	13	13	13
63 to 70	12	14	12	9	13	14	18	15

treatment of sockeye salmon. Gantrisin has the lowest growth-retarding effect on brook trout. In this respect, sulfamerazine is the second best. The effect of sulfamethazine on the growth of this species still remains undetermined. Nothing is known yet about the effect of sulfonamides on the growth rate of salmon. Also, more information is needed on the tissue levels, optimum dosage, and the length and frequency of treatments of the kidney disease in salmonid fishes.

All available data indicate that at the present time a permanent cure of kidney disease in salmonid fishes is still not possible. Because kidney disease has a seasonal character, it may be possible to keep the disease under control by judicious use of sulfonamides. Epizootiological observations permit determination of the course of this disease in various species of salmonid fishes and under different conditions at various hatcheries, in this way determining the time at which the prophylactic therapy could be expected to be most effective. Data accumulated from such treatments should permit further improvements in the control of this disease.

Further studies should be made on the transmission of kidney disease. It seems to be spreading rapidly among some species of salmon in the western hatcheries and in brook trout at the Berlin hatchery and possibly at other eastern hatcheries. At the Leetown Station several fingerling trout with advanced symptoms of this disease were found among large populations of brook trout, but this infection was limited to sporadic cases without any control measures. The data furnished by Earp, Ellis, and Ordal (1953: 64) as showing that the disease was transmitted by feeding are not convincing. The tests here reported indicate that brook trout exposed to infection by contact or by feeding did not develop the infection during the observation period lasting several months.

In light of the fact that "salmon poisoning" of dogs is transmitted by a fluke, Troglotrema salmincola, it seems possible that a parasitic vector may also be responsible for the transmission of kidney disease in salmonid fishes. This may be inferred from the observations that this disease appears in epizootic proportions in hatcheries receiving water from open streams which may contain parasites that transmit this disease. In hatcheries like that at Leetown, where water flows from a spring by a closed system, infestations of trout by parasites are infrequent. Such paucity of trout parasites which could spread kidney disease may have been the cause of a very limited appearance of this disease among the Leetown trout.

On the basis of the information now available, it is believed that Gantrisin, sulfamerazine, and possibly also sulfamethazine are the sulfonamides of choice. The use of 8 to 10 grams per 100 pounds of fish per day produces satisfactory tissue levels (Snieszko and Friddle 1951; data on Gantrisin will be published separately). In case of an outbreak, the therapy should be continued until mortalities due to kidney disease drop to a very low level. It should be repeated for weekly periods every month, or at shorter intervals, until the season for this disease is over. For brown trout, only Gantrisin should be used, as all other sulfonamides so far tested at Leetown arrest the growth of this species. The drug should be well mixed with food; the fish should be graded so that all will obtain an equal amount. Excessive amounts of drugs should not be used, for such a procedure is experimentally unjustified and wasteful. The low dosages should be avoided because they may be ineffective and cause appearance of drug-resistant varieties of the pathogen. A multiple therapy with a mixture of two or three of the above-listed sulfonamides may give better results. However, no experimental support is yet available for a multiple therapy of kidney disease in salmonid fishes.

Summary

1. Experiments on kidney disease in brook trout were conducted in the hatchery at Berlin, New Hampshire, and in the Microbiological Laboratory at Leetown, West Virginia.

2. The following drugs were tested: sulfamerazine, sulfanilamide, sulfadiazine, sulfathiazole, Gantrisin, chloramphenicol, terramycin, and aureomycin.

3. Satisfactory control of the disease was obtained with all sulfonamides. Gantrisin and sulfamerazine had the least retarding effect on the growth of brook trout.

4. The factors that may contribute to the spread of this disease are discussed.

5. Recommendations for treatment are outlined, in so far as possible, on the basis of the data now available.

Acknowledgments

The authors wish to thank Mr. W. F. Carbine and Drs. A. M. Phillips, Jr. and E. M. Wood for critical reviews of the manuscript and for many valuable suggestions. The authors also wish to express appreciation to Dr. R. R. Rucker of the U. S. Fish and Wildlife Service, Dr. L. B. Tennison, Jr. of the Lederle Laboratories, and Dr. J. A. Aeschliman of Hoffmann-La Roche, Inc., for reading the manuscript and for their interest in these investigations.

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RESULTS OF PLANTING CATCHABLE-SIZE BROWN TROUT, *SALMO TRUTTA FARIO* L., IN A STREAM WITH POOR NATURAL REPRODUCTION

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IN SOME HEAVILY USED TROUT-STREAM AREAS it is desirable to maintain fishing in streams where natural reproduction is negligible but where conditions will support catchable-size planted trout. When fishing can be provided at reasonable cost in such waters, general management will be improved by distribution of the fishing load.

To test certain aspects of this procedure, Watson Creek in southeastern Minnesota was selected for study. Watson Creek permitted little, if any, natural reproduction and, in general, appeared to be a marginal trout water. Marked brown trout (Salmo trutta fario L.) were planted in the fall to determine overwinter survival, contribution to anglers' catch, and practicability of this type of management. Complete creel census was maintained in the season after planting, and periodic checks with the electrical shocker were made to determine the status of the population during the experiment. The work was done as part of a general program of trout investigations conducted by the Fishery Research Unit of the Minnesota Department of Conservation.

Watson Creek originates in a limestone cavern which underlies a limestone sink region. Its normal flow ranges from approximately 3 to 5 cubic feet per second but in dry seasons may be less and during rain storms may carry 47 cubic feet per second. There are occasional flood crests of 6 feet after severe thunder storms, and flood debris has been noted 12 feet above the level of normal flow. When flow is normal, the water is hard and has a total alkalinity in excess of 140 parts per million. The upper 2 miles of the stream channel, which was considered the only trout water on the system, lies in recently cleared and heavily grazed land. The stream bottom is composed of approximately 52 percent rubble and gravel, 38 percent silt and sand, and the remainder comprising several soil types.

The growing season in the vicinity of Watson Creek is long (142 days), and the winters are mild. During January, the coldest month, the mean temperature is 12.5° F. Only light ice is found on the stream, and the rigorous winter conditions observed in more northerly parts of Minnesota do not normally occur in Watson Creek. The open nature of the area surrounding the stream permits summer water temperatures to rise occasionally as high as 80° F., but the heavy spring flow in the upper section usually provides areas of suitably cold water during critical periods of the day. The lower stretches of Watson Creek are too warm to maintain trout, forming an

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effective barrier to downstream movement during the summer.

METHODS

In order to determine the effectiveness of trout planted in the fall to maintain fishing during the following summer season, 1,625 brown trout were placed in the upper 2 miles of Watson Creek during the latter part of September 1948. All fish ranged from 4.7 inches to 12.7 inches in length and were marked by removal of the pelvic fins. During the entire 1949 angling season, a direct-contact creel census was maintained over the trout area of the stream. On the opening 2 days of the season a complete census of all anglers was taken, and thereafter complete check was made on alternate days. Final results were calculated on the basis of these contacts.

Estimation of the total fish population in the stream was made at intervals by the electrical-shocking method similar to that employed by Shetter (1947). Care was taken to select sections that included both riffles and pools and that were representative of the different portions of the stream. Twelve stations were established in 1948 and were used again in 1949, with the exception of one that was considered too deep to shock effectively.

THE 1949 CREEL CENSUS

During the 1949 angling season, 358 fishermen caught 481 trout from Watson Creek. Of this group, 478 fish were fin-clipped, 2 were unmarked brown trout, and 1 was an unmarked brook trout. These anglers spent 1,047 hours on the stream and caught trout at the rate of 0.6 per hour. At the close of the first 2 days of fishing, 63.5 percent of the total catch of the year had been made; and by the end of the 4th week, 80 percent had been taken. These results are comparable to those found by Smith and Smith (1945) in Duschee Creek, another southeastern Minnesota trout stream, and are similar to results reported elsewhere in the literature. As the season progressed, the number of trout caught each week fell off rapidly, but the rate of catch remained relatively uniform. This maintenance of average success through the season is probably attributable to the much greater skill of the late-season anglers when compared to the average skill of the spring anglers. Forty percent of the total angling effort for the season was made on the opening weekend; and at the close of 4 weeks, 71 percent had been expended. After the close of the 5th week, fishing effort fell off rapidly, although the entire season covered 20 weeks.

FISH POPULATION OF WATSON CREEK

In order to evaluate the total production of fish, the survival of marked trout, and the relation between planted fish and the resident population in Watson Creek, a series of population estimates was made with the electrical shocker in mid-July 1948, on June 25, 1949, and again on September 21, 1949. Smith, Johnson, and Hiner (1949) reported on the standing population of Watson Creek in 1945 from a 0.36-acre sample. Their data permit an evaluation of trends when compared to the results of the present study (table 1). In 1945 there was a total of 109 pounds of fish per acre. Of this weight, trout comprised 33 pounds, suckers (Catostomus c. commersonii) comprised 59 pounds, and other fish comprised 17 pounds. The weight of miscellaneous fish was made up primarily of longnose dace (Rhinichthys c. cataractae), 14.9 pounds, and stone rollers (Campostoma anomalum pullum), 1.46 pounds. In 1948 a 1.95-acre stream sample indicated a total of 195 pounds of fish per acre, of which trout comprised 17 pounds, suckers comprised 126 pounds, and forage fish[1] comprised 52 pounds (table 1).

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[1] Forage fish include: Boleosoma n. nigrum, Poecilichthys flabellaris lineolatus, Campostoma anomalum pullum, Rhinichthys c. cataractae, Rhinichthys atratulus meleagris, Semotilus a. atromaculatus, and Pimephales p. promelas.

There was a further change in the fish population between July 1948 and June 25, 1949. On the latter date, when 2.15 acres were shocked, 207 pounds of fish per acre were taken. Of this weight, trout comprised 13 pounds, forage fish comprised 42 pounds, and suckers comprised 152 pounds. The continued shift toward greater production of suckers and other warm-water species may be associated with a progressive physical deterioration of the stream. Whether or not this shift toward a more favorable warm-water habitat continues, the stream must be regarded at present as essentially a marginal trout stream or a warm-water stream insofar as the fish population is concerned.

TABLE 1.--Weights of trout, suckers, and forage fish in Watson Creek, 1945, 1948, and 1949, listed as pounds per acre, and numbers of trout per mile

Item	1/ 1945 (October)	2/ 1948 (July)	1949 (June 25)
Number of stations------	4	12	11
Area shocked-----acres--	.36	1.95	2.15
Number of trout---------	140.00	51.00	70.00
Weight of fish:			
Trout----------	33.00	17.00	13.00
Sucker----------	59.00	126.00	152.00
Forage fish 3/---------	17.00	52.00	42.00
Total----------	109.00	195.00	207.00

1/ Smith, Johnson, and Hiner (1949).
2/ Kuehn (1948).
3/ See text.

SURVIVAL OF FALL-PLANTED TROUT

The wide variation in reported survival of the fall-planted brown trout until the following angling season, which has been reported in the literature, makes the efficiency of such planting questionable. Needham, Moffett, and Slater (1945) noted that survival of wild brown trout in Convict Creek varied with the severity of the winter, but that over a 3-year period there was an average survival of 40 percent of all size groups. On the basis of returns to the angler, Smith and Smith (1945) showed a survival of 21.7 percent in Duschee Creek and 1.4 percent in Knife River, a northeastern Minnesota stream. Other authors have shown survival to the creel as ranging from 3.2 to 56.4 percent.

As actual catch by anglers and survival in the stream may not be the same, the mortality of fall-planted brown trout in Watson Creek was checked by shocking on April 12, June 25, and September 21 in the season that followed the fall planting. The number of fish available in the stream prior to the opening of the fishing season in 1949 had to be estimated on the basis of results from 7 of the 12 stations shocked in June and September. This calculation was based on the assumption that the relative number of fish at the various stations was similar in April and June.

On the basis of the April estimate, it was determined that 696 fish, or 42.8 percent of the 1,625 trout planted in the previous September, had survived to the beginning of the following fishing season (table 2). By June 25, after 433 trout had been taken by anglers, the population estimates showed that only 124 trout, or 7.6 percent of the original planting, remained in the stream. On September 21, after the close of the fishing season, it was estimated that 58 fish, or 3.6 percent of the 1948 fall planting, had survived. It appears, therefore, that of the original number of trout planted, 57.2 percent succumbed to natural causes before the fishing season, an additional 9.8 percent were lost from natural mortality during the angling season, and 29.4 percent were taken by anglers. Of the fish available in the stream at the beginning of the fishing season, 68.7 percent were taken by the anglers, 23 percent were lost from other causes, and 8.3 percent remained at the close of the season.

Because there is no competition from wild trout and carryover from previous plantings is negligible, there is little or no predaceous competition for the planted trout except from their own numbers.

TABLE 2.--The number of marked brown trout planted in Watson Creek in the fall of 1948 and the calculated number surviving at various times during the ensuing 12 months

Date	Months fish were in stream	Number in stream	Number taken by anglers to date	Percentage survival of fall plant	Percentage survival of fish available April 12
Sept. 1948	----------	[1] 1,625	----------	100.0	----------
Apr. 12, 1949	6.50	[2] 696	----------	42.8	100.0
June 25, 1949	9.00	[2] 124	433	7.6	17.8
Sept. 21, 1949	11.75	58	478	3.6	8.3

[1] Planted after the close of the 1948 fishing season.
[2] 133 were in the stream, but 9 died during shocking on a hot day.

Under these conditions it is probable that survival and contribution of the planted fish to the creel are higher than would be found in streams where there was a resident trout population. There also is evidence that winter conditions in 1948-49 were less severe than normal and therefore more conducive to high overwinter survival.

GROWTH OF PLANTED TROUT

One of the reasons advanced for fall planting of trout is that the fish grow over winter and thereby give the anglers a more satisfactory catch, which in part offsets the poor survival. To determine the significance of this growth, the average length and weight of the marked fish at the time of planting were determined from three samples taken at intervals during the marking procedure. The combined sample of 296 fish ranged in length from 4.7 inches to 12.7 inches, with an average of 7.2 inches (table 3; figure). The average weight of 265 fish at the time of their marking was 0.16 pound. From the date of marking in September to the following April 12, 196 of the surviving fish had an average length of 8.1 inches (range, 5.1 to 11.8 inches) and an average weight of 0.24 pound. Average overwinter growth of the trout was 0.9 inch and 0.08 pound. Whether this growth was actual increment or represented a selective survival of larger fish has not been determined. On June 25, trout had an average length of 9.0 inches (range, 6.8 to 14.4 inches). After the close of the fishing season (September 21), the fish had not increased in average length, being still 9.0 inches (range, 7.2 to 11.4 inches). The apparent failure to grow during the summer is probably related to the selection of larger fish by the anglers, as the lower limit has increased and the larger fish are absent in the September sample.

COST OF PLANTED FISH

In the evaluation of a management procedure, cost of operation must be considered in conjunction with its effectiveness. On the basis of a cost of $2.40[2] per pound of trout delivered to the stream, each fish was worth $0.38 when it was planted. Because survival to the creel was 29.4 percent, each fish taken by an angler cost $1.26. If the cost of fall-planted trout actually available to anglers at the start of the season is estimated on the basis of overwinter survival rate, each trout was worth $0.95. On the basis

[2] The Bureau of Fisheries, Minnesota Department of Conservation, estimates the cost of "yearling" trout (approximately 18 months) to be $2.19, 8 to 10 per pound, without inclusion of administrative overhead, biologist services, etc.; with the latter items included, the average cost for the years 1950, 1951, and 1952 was $2.40 per pound. Recent economies in food and operational costs have reduced this total somewhat for current operations.

of weight, considering the overwinter increment of surviving fish, each pound of planted fish available at the beginning of the season was worth $3.74.

CONCLUSIONS

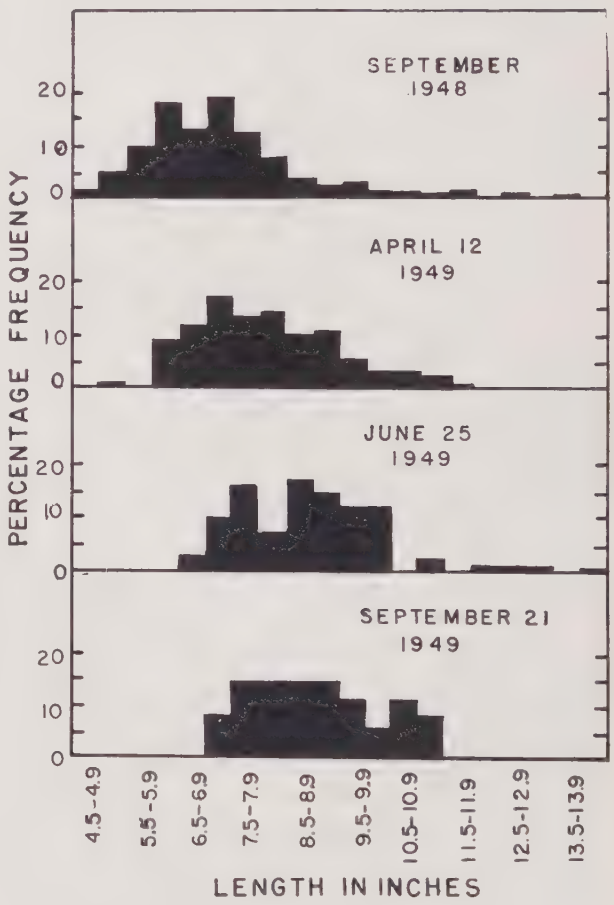
The nature of the fish population in Watson Creek, especially the absence of trout reproduction and the predominance of warm-water species, indicates that this water is of marginal quality for trout and that trout fishing can be maintained only by the efficient planting of catchable-size fish. The progressive trend in fish populations toward a proportionally higher abundance of warm-water species since 1945 suggests that trout management of any sort may become impractical unless stream deterioration is stopped and the trend is reversed. In the present experiments, fall planting of brown trout appears considerably more expensive than planting during the season or immediately prior to it would be. The apparent growth over winter, whether actual or the result of differential mortality, does not offset the overwinter loss in numbers. This apparent growth may provide the angler with somewhat larger fish than would be available from the spring planting.

Whether better fishing would be maintained by seasonal or spring planting of fish cannot be determined without further experiment. Studies in other parts of the same area suggest that survival to the creel is lower than could be anticipated from spring planting, but the specialized character of the fishing load might prevent full harvest of available fish during midseason, even though they were present in quantities. The high cost for maintenance of trout fishing in this stream appears to be justified only if the general management of the area requires the inclusion of additional waters to carry the heavy spring fishing load.

TABLE 3.--Average total length and size range of fin-clipped brown trout at time of marking in the fall of 1948 and at three times in the following fishing season

Date	Number of fish	Average total length	Size range
		inches	inches
Sept. 1948	1/296	7.2	4.7 - 12.7
Apr. 12, 1949	196	8.1	5.1 - 11.8
June 25, 1949	82	9.0	6.8 - 14.4
Sept. 21, 1949	30	9.0	7.2 - 11.4

1/At hatchery prior to stocking.



Length frequency of stocked brown trout at time of stocking in September 1948 and in April, June, and September, 1949, expressed as percentage of total fish in sample on the various dates.

(Courtesy of the authors)

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BENTONITE AND LARGEMOUTH BASS EGGS

A study made by Kenneth C. Jurgens and William H. Brown, aquatic biologists with the Texas Game and Fish Commission, indicates that bentonite has no ill effects on largemouth bass eggs.

For experimental work to determine the effect of various low temperatures, largemouth bass eggs were collected from a relatively large nest in a hatching pond at the Heart O'Hills State Fish Hatchery near Ingram, Kerr County, Texas. The eggs were then washed and divided into 12 approximately equal portions. A summary of the results obtained from 11 of these portions has already appeared in The Progressive Fish-Culturist (October 1954).

Because of the extensive use being made of bentonite and the possibility that this powdered clay was affecting the production in many ponds, the 12th group of these eggs was brought into direct contact with the bentonite. The bottom of a watch glass was coated with bentonite. The eggs were placed in this watch glass, which was then put in a fine-mesh nylon bobbinet sack. This sack of eggs, like the 11 others, was finally suspended--about 4 inches from the bottom--in a 2-quart fruit jar that was filled from the hatchery water supply.

At the conclusion of the experiment it was determined that contact with the bentonite did not kill the bass eggs, and that there was no apparent harm in the continued use of this material to seal pond bottoms.

"At the outset of this experiment," write Jurgens and Brown, "the development of the embryos indicated that the eggs were approximately 12 to 15 hours old. ... Frequent examination under the microscope showed that bentonite had no effect on the eggs. All the eggs developed normally, hatching within 60 hours after the estimated time of fertilization."

During the first 6 weeks of a drift study on Lake Michigan, recoveries indicated that sealed glass bottles with drag attachments were more than twice as efficient as either plastic envelopes or plastic tubes with drag attachments.

THE HATCHING OF CHINOOK SALMON EGGS UNDER SIMULATED STREAM CONDITIONS

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INVESTIGATION OF THE HATCHING OF EGGS OF THE CHINOOK SALMON, Oncorhynchus tshawytscha, under simulated stream conditions was initiated in the latter part of 1952 at the Little White Salmon Fish-Cultural Station of the U. S. Fish and Wildlife Service near Cook, Washington. The project was undertaken to determine the feasibility of planting chinook salmon eggs in gravel beds, a management procedure considered in the search for varied and economical means of expanding the production of salmon in the Lower Columbia River.

As early as 1910, fishery workers experimented with the burial of salmon eggs as a method of hatching salmon and trout (Babcock 1911). Since that time many fishery workers, such as Carl (1940), Foerster (1946), Shapovalov (1937), Shapovalov and Berrian (1940), and Wickett (1952), have worked on the planting of salmonid eggs in gravel. Aside from the work done by Wickett, the findings of these men were not applicable to the particular problem of increasing the production in the Lower Columbia River. Wickett's findings (1952) in connection with chum salmon, O. keta, and pink salmon, O. gorbuscha, seemed to indicate the possibility of similar success with chinook salmon in the Lower Columbia River.

Hatchery ponds located at the Little White Salmon Station were used to set up artificial gravel beds, and factors such as water depth, volume, and velocity were controlled. Gravel sizes, depths of gravel above the eggs, percentage hatch, egg mortality, rate of fry emergence, and percolation, in addition to water characteristics, were studied. The work was started early in November 1952 and was completed in July 1953.

EQUIPMENT AND PROCEDURE

Plastic-Screen Bags

To prevent the escape of any fry during this study of the factors that affect the hatching of eggs in gravel, salmon eggs were placed in plastic-screen bags. The bags were made of plastic screen because this material would not rot or deteriorate while the eggs were in the water and would allow the necessary movement of the water. A clear plastic screen, 12 mesh to the inch, was cut into strips and made into 10- by 11-inch bags. Plastic screen of two filament sizes, 0.020- and 0.015-inch, was used. No material difference was found in the egg mortality or hatching within bags of these two filament sizes. The strips of plastic screen were sewed on household sewing machines with nylon thread.

It has been found that the depth of the gravel above eggs in natural redds varies to some degree. Parker and Kirkness (1950), using the planting of eggs in gravel as a tool of management, planted salmonid

eggs at various depths from 8 to 18 inches below the stream bed in a suitable gravel riffle. The objective of their work was to form a successful nucleus of fall-spawning chinook salmon. With such findings and work as a guide, the present investigation included plans to have 3, 6, and 12 inches of gravel placed above the plastic bags of eggs.

As the first step in preparation for use, a single plastic bag containing a small amount of gravel was held under water and 100 eggs were placed in the bag. Additional gravel, enough to cover the eggs, was put in the bag. Then, after it had been tied, the bag was buried in the gravel bed, the tied end of the bag upstream directly behind a lath marker driven into the gravel. Location of the gravel beds is shown in figure 1. The location of the bags is shown in figure 2.

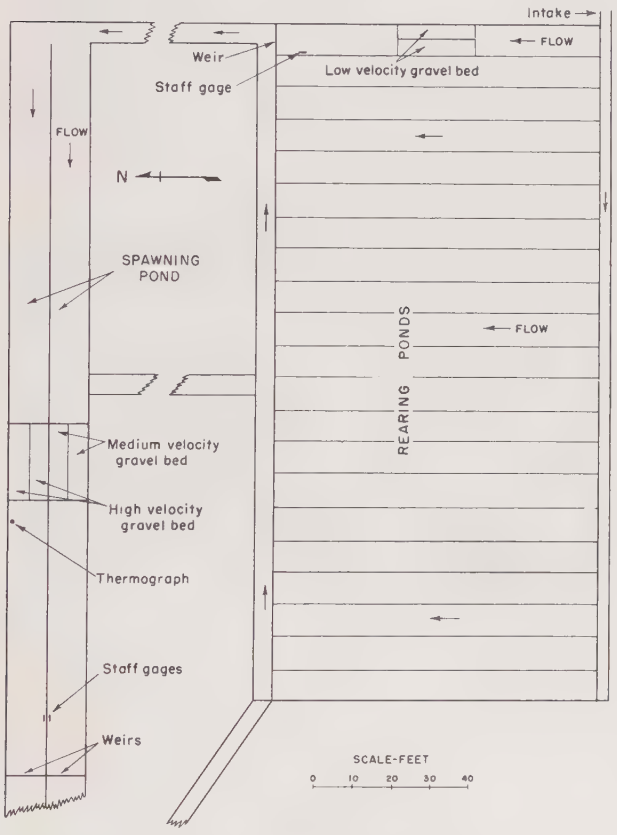

FIGURE 1.--Plan view of rearing and spawning ponds at Little White Salmon Fish-Cultural Station.

Screened Boxes

The rate of emergence of the fry from the gravel was determined by planting eggs so that they were free in the gravel but surrounded by screened boxes with sides reaching above the gravel surface and thus preventing their escape immediately after emergence. These boxes were made of wooden frames covered with plastic screen.

Burner (1951) found that the depth of chinook salmon redds ranged from 2 to 20 inches. For this project, therefore, 4 different depths of gravel (3, 6, 12, and 18 inches) above the eggs were chosen in 2 gravel types and 3 velocities of water, making a total of 24 boxes. Each box had a bottom 12 inches square and a height determined by the depth of gravel above the eggs. Allowance for an approximate 9-inch depth of water, a 3-inch extension above the water, and 3 inches of gravel below the egg level made the boxes 18, 21, 27, and 33 inches in height. After a hole had been dug in the gravel, a suitable screened box was placed at the desired depth. Gravel (approximately 3 inches) was placed inside the box, and 100 eggs were lowered by hand into the water above the gravel. Gravel was placed over the eggs, a handful at a time, with reasonable care that the eggs were not smashed or crushed. After 3 or 4 inches of gravel had been placed over the eggs, enough additional gravel was provided to make it level with the gravel surrounding the box. A screen was placed over the box so that the fry would not be molested by sea gulls, Larus sp., or water ouzels, Cinclus mexicanus, which were in the area.

Velocity, Temperature, and Flow Apparatus

The velocity of the water flowing over the gravel was measured by using a pigmy current meter. A recording thermometer provided a constant record of the temperature during the entire experiment. Standard Cippoletti weirs were placed near the downstream ends of the ponds, and periodic flow measurements were

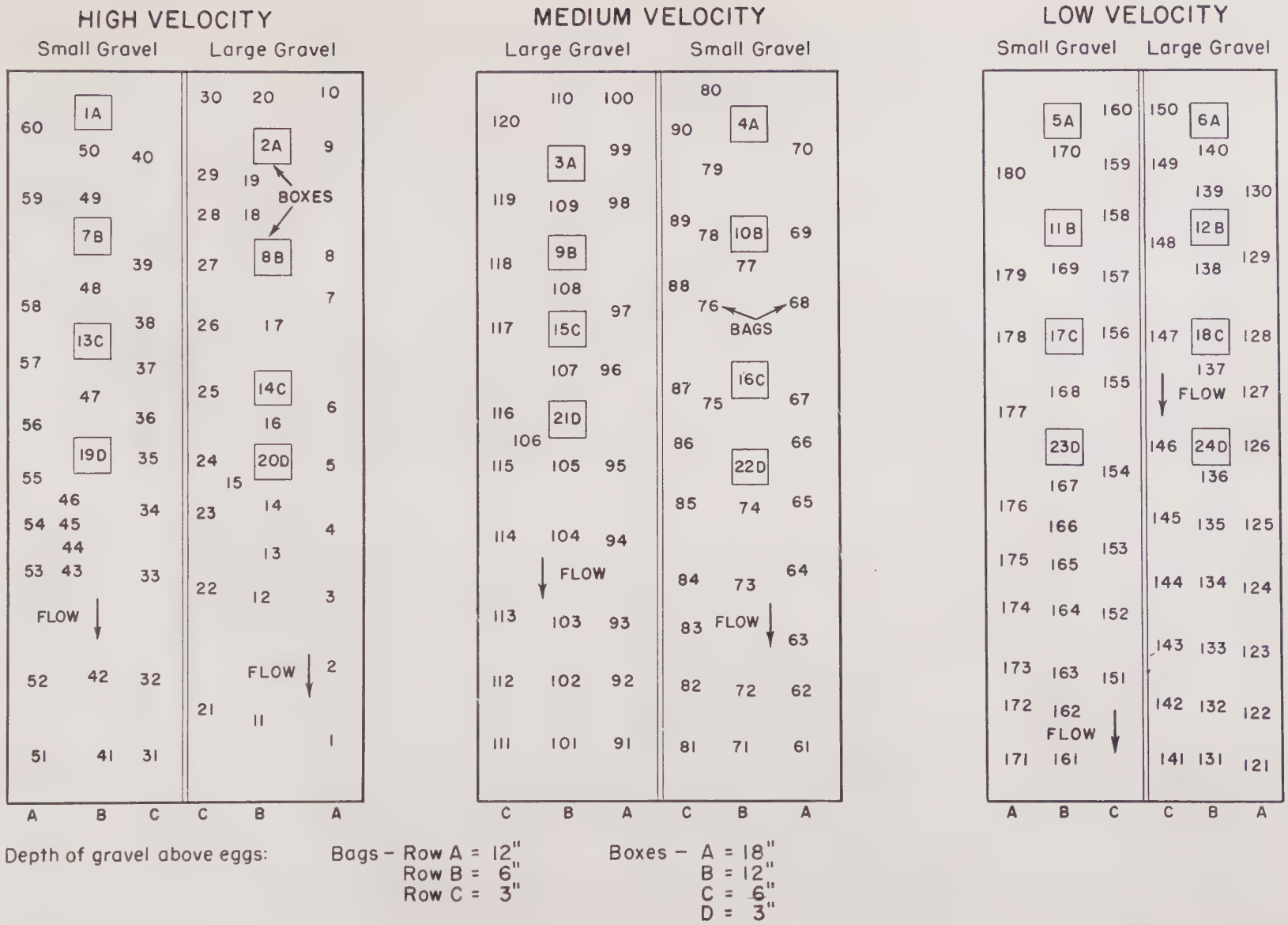

FIGURE 2.--Location of plastic bags and screened boxes in ponds.

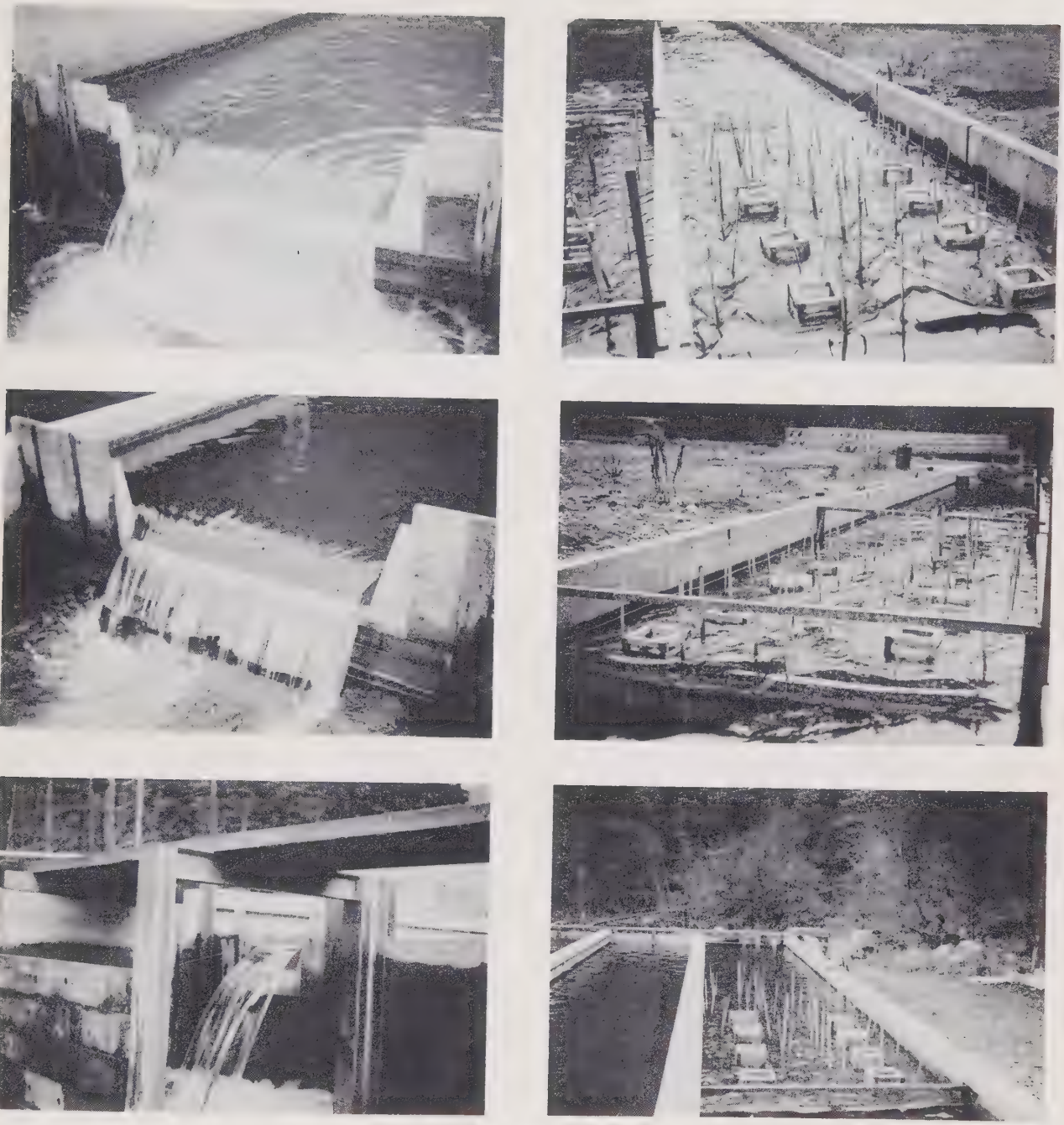

FIGURE 3.--From top to bottom: ponds of high, medium, and low velocity, with corresponding weirs.

made with the aid of staff gauges located a few feet upstream from the weirs.

During the project there were slight changes in the volume of water because of temporary diversion of part of the water for normal hatchery operation and maintenance. In the high-, medium-, and low-velocity ponds the average flow of water was 9.7, 6.0, and 1.2 cubic feet per second, respectively. See figure 3.

Subsurface Flow Instrument

It was believed that the percolation of water through the gravel might be one of the most important factors governing the hatching of the eggs, but suitable equipment was not available to secure a true picture of the flow through the gravel at depths ranging to 24 inches. The fact that water becomes a good conductor of electricity when certain ionized salts are added prompted the use of a conductivity measurement as an aid in determining the percolation of water through the gravel. A wooden rod, 1.25 inches in diameter and 42 inches long, was used as a support for the attachment of 4 sets of brass electrodes. The electrodes were 16-gauge brass plate, 0.25 inch wide and 1.5 inches long. The bottom of the first set of electrodes was placed 4.5 inches from the end of the rod. The bottoms of the other sets were 10, 15.5, and 19.5 inches from the end of the rod. Each individual electrode plate was attached to a single insulated wire that ran up the side of the wooden rod and could be connected to a voltmeter and a battery. A small box was used to hold a small voltmeter, a series of batteries, a master switch, and a switch constructed so that the 4 sets of electrodes might be connected in parallel. The point of the wooden rod was covered with a metal tip so that the wood would not splinter while being driven into the gravel. Two metal rods, 0.5 inch in diameter and 36 inches long, were insulated entirely with the exception of 4 inches on one end. These rods, also connected to the meter box, were driven (about 2 inches apart) into the gravel beside the wooden rod to serve as a set of electrodes for determining any flow directly on the bottom of the pond. The conductivity rods and meter box are shown in figure 4.

When the electrodes were placed in water, the normal electrical conductivity of the water was indicated on the voltmeter. When sodium chloride solution was added, an immediate increase in the conductivity of the water was indicated by an increased reading on the voltmeter. In practical use, a weak solution of sodium chloride was used in determining the velocity of water in the gravel, because the heavier weight of a concentrated solution caused it to sink rapidly to the bottom of the pond. A number of trials, both within and without the gravel beds, showed that a sodium chloride solution of 2,600 parts per million would give a satisfactory reading on the voltmeter for the chosen test conditions of a 12-inch distance between the introduction of solution and the electrode position.

For a reading, both insulated metal rods and the wooden rod were driven to the bottom of the 24-inch gravel beds at a designated place. The sodium chloride solution (2,600 parts per million) was then introduced, 1,000 cubic centimeters at a time, at a given depth below the surface of the gravel, 12 inches upstream from the electrodes. The period that then elapsed between the introduction of the sodium chloride solution and the indication of an increased reading on the voltmeter represented the maximum amount of time required for the water current to travel 12 inches. Four stations were used in each size of gravel within each of the 3 ponds, making a total of 24 stations. In the bed of large gravel within the high-velocity pond, 2 stations were located 5 feet from the upstream end of the gravel bed, about 15 inches from each side of the bed. Also, 2 stations were located 1 foot from the downstream end of the large-gravel bed, 15 inches from each side. A set of similar stations was chosen for each size of gravel in each of the 3 ponds.

PHYSICAL FEATURES

Gravel Bed

Dimensions. -- The dimensions of the gravel beds were determined by the size of the ponds and the surface area required to place a specified number of plastic bags and screened boxes in the gravel. Allowing approximately 2.5 square feet of surface area for each bag, it was determined that 20 feet would be ample for the length of each gravel bed. The gravel beds were 8 feet wide in the rearing ponds and 10 feet

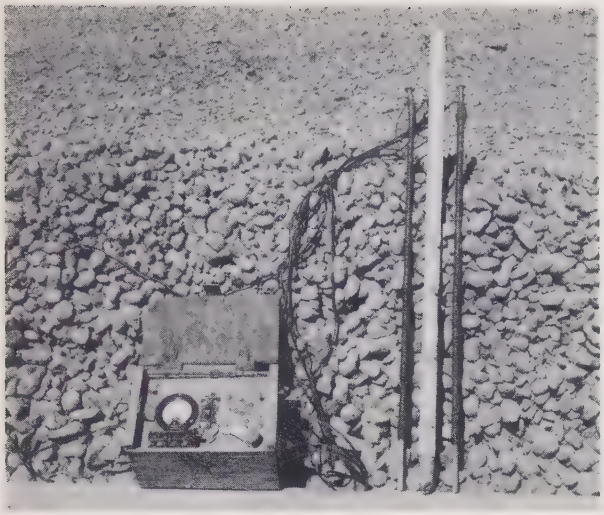

FIGURE 4.--Conductivity rods and meter box.

FIGURE 5.--Type and size of gravel used in projects.

wide in the spawning ponds. The depth in all ponds was 2 feet. The gravel was held in place on the upstream and downstream sides by use of galvanized-wire screen, 5 mesh to the inch, 16-gauge.

Size of Gravel. --The size of gravel used in this work was determined largely by gravel sizes found in natural redds. Burner (1951) described redd gravel as small, medium, or large, the small being less than 3 inches; medium, 3 to 6 inches; and large, more than 6 inches. This size seems nearly to parallel the findings of other investigators. Gravel for the tests, hauled from a nearby sand-and-gravel company, was in two sizes--1 to 3 inches in diameter, and 1 inch and less in diameter. All of the gravel was washed and cleaned; there was essentially no dirt or sand. The larger gravel had a very small percentage of crushed rock, estimated to be less than 5 percent. The two ranges of gravel size were used in each of the three ponds and separated by a 1-inch board wall extending the length of the pond. Figure 5 shows the type and size of gravel used.

Water Characteristics

Temperature. --The lowest temperature, 36.5° F., occurred on December 28; the highest, 49.5° F., occurred on May 5. A gradual increase of both maximum and minimum temperatures occurred as the project extended from winter into spring (figure 6). The maximum temperature was 40.5° F. by January 6, when hatching was completed in the samples examined. The water temperature for the week previous to this date had remained within 1.5° of 40° F. From the time the eggs were planted until the latter part of February, the daily range between the maximum and minimum temperatures was 1° or 2°. As the season progressed into late spring, the range gradually became greater, and at times there was a difference of as much as 6° between the maximum and minimum.

Velocity. --Throughout the project, a different surface water velocity was maintained in each of the three ponds--which are hereafter referred to as the high-velocity pond, the medium-velocity pond, and the low-velocity pond. In the high-velocity pond, the range outside the screen boxes was from 0.4 to 3.5 feet per second, the average being 2.2 feet per second. The surface velocity inside the boxes after they were cleaned ranged from 0.5 to 1.7 feet per second. Outside the boxes of the medium-velocity pond, the range was from 0.1 to 2.3 and the average was 1.2 feet

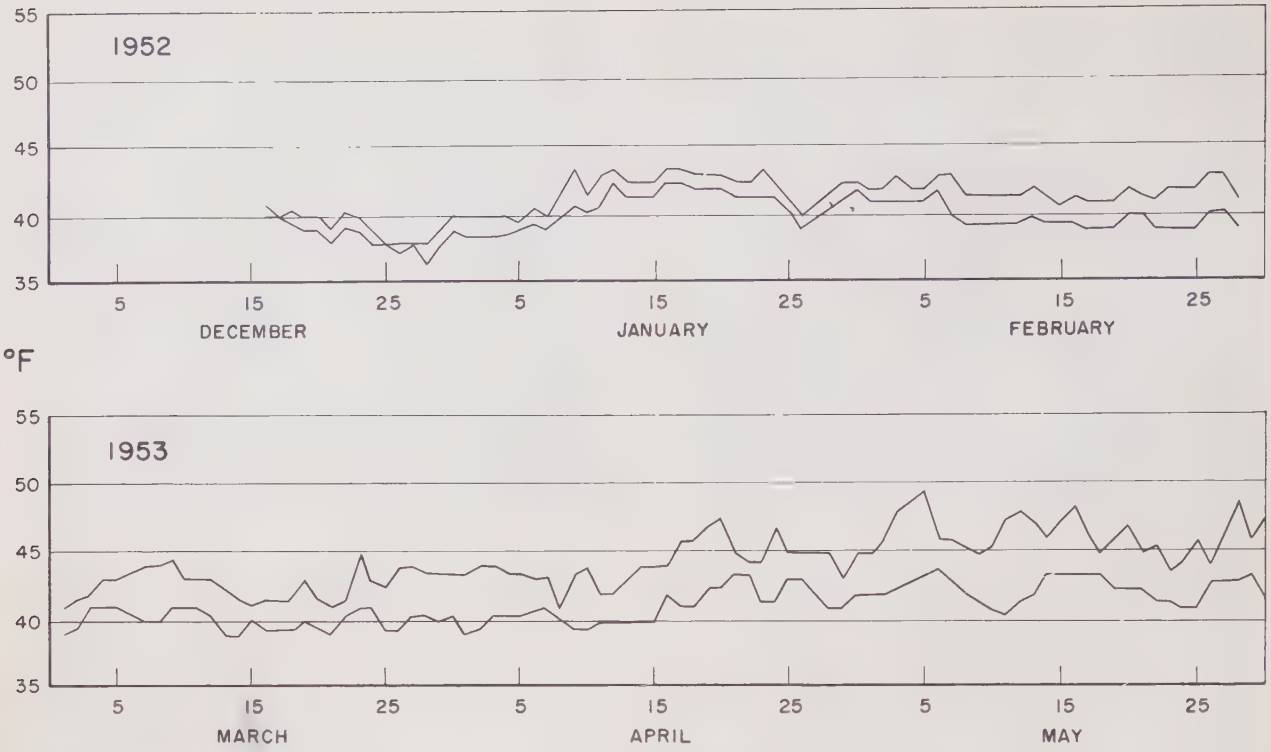

FIGURE 6.--Maximum-minimum water temperature during project.

per second. The range inside the cleaned boxes was from 0.2 to 1.1 feet per second. The range outside the boxes of the low-velocity pond was from 0.1 to 0.9 foot per second; the average velocity was 0.4 foot per second. The low-velocity pond had a range of less than 0.07 to 0.2 foot per second within the cleaned boxes. The surface velocity inside the screen boxes dropped to less than 0.1 foot per second when the screens became clogged with debris.

CONTROLS

Efficiency of Plastic Bag

In the event that the resulting data displayed an exceptionally high mortality of eggs, this result might be attributed to some type of toxic or inhibitive effect that the plastic had on the eggs, or to the percolation or movement of water within the gravel bed. The percolation factor was to be checked by special means in the gravel beds, but any high mortality resulting from the presence of plastic must be ascertained by some special control where the important single factor of percolation was satisfactory.

To make such a test, 4 plastic bags with gravel and 100 eggs in each were put on regular trays within the hatchery troughs on December 19, 1952. To insure the movement of water through the gravel within as well as around the bags, all 4 bags were surrounded by gravel. Two plastic bags contained, and were surrounded by, small gravel. The gravel used here was the same size as the gravel in the ponds.

The eggs were in the eyed stage and approximately 79 days old when planted. Two of the bags were removed from the hatchery troughs on January 2, 1953, when the eggs were approximately 93 days old. One of these bags contained eggs that had been surrounded by large gravel both inside and outside the plastic bag; the other contained eggs that had been surrounded

by small gravel both inside and outside the bag. One bag contained 99 fry and 1 dead egg that had been crushed during the handling. The other bag displayed a hatch of 100 percent.

The remaining 2 bags were removed from the hatchery troughs on January 23, 1953, when the eggs were approximately 114 days old. Large gravel was used for 1 bag and small gravel for the other, as in the first set of bags. One bag contained 94 fry and 6 dead eggs which had been crushed during handling. The remaining bag contained 98 fry and 2 dead eggs, 1 of which had been crushed.

The two bags with large gravel contained a hatch of 97 percent. The bags with small gravel contained a hatch of 98.5 percent. The 4 bags produced a hatch of 97.8 percent. Data on the hatch and mortality in the bags placed in the hatchery troughs are presented in table 1.

Injury Due to Gravel

It was considered feasible to include a check on any egg mortality due to injury from a given type of gravel, as opposed to mortality due to lack of percolation or to excess of percolation. Eggs were placed in plastic bags filled with small gravel, and the bags were surrounded by large gravel. In addition, eggs were placed in plastic bags filled with large gravel, and

TABLE 1.--Hatch and mortality of eggs located in Warm Springs River and in hatchery troughs of the Little White Salmon Fish-Cultural Station

Bag number[1]	Date	Age of eggs (days)	Number of eggs	Hatched		Dead		Type of gravel
				Number	Percent	Number[2]	Percent	
1	12-17-52[3]	77	100	100	100.0	0	0	Sand and gravel to 8 inches.
	1- 8-53[4]	99						
2	12-17-52[3]	77	100	96	96.0	1	1.0	Sand and gravel to 8 inches.
	1- 8-53[4]	99						
3	12-17-52[3]	77	100	99	99.0	(1)	1.0	Sand and gravel to 8 inches.
	1- 8-53[4]	99						
4	12-17-52[3]	77	100	99	99.0	0	0	Sand and gravel to 8 inches.
	1- 8-53[4]	99						
Totals			400	394	98.5	2 (1)	.5	
5	12-19-52[3]	79	100	94	94.0	(6)	6.0	Gravel, 1-3 inches in diameter.
	1-23-53[4]	114						
6	12-19-52[3]	79	100	100	100.0	0	0	Gravel, 1-3 inches in diameter.
	1- 2-53[4]	93						
7	12-19-52[3]	79	100	98	98.0	2 (1)	2.0	Gravel, to 1 inch in diameter.
	1-23-53[4]	114						
8	12-19-52[3]	79	100	99	99.0	(1)	1.0	Gravel, to 1 inch in diameter.
	1- 2-53[4]	93						
Totals			400	391	97.8	9 (8)	2.3	

[1] Bags 1 to 4, in Warm Springs River; 5 to 8, in Little White Salmon hatchery troughs.
[2] Eggs crushed or broken are shown in parentheses.
[3] Eggs were planted.
[4] Eggs were removed.

these bags were surrounded by small gravel. This situation was duplicated for each water velocity and for each depth of gravel above eggs. It was considered unnecessary to check this study of gravel size every week. One group of 18 bags was removed near the calculated halfway mark, and another group at the end of the development period. Comparison of mortality due to unknown causes (primarily percolation) under the different sets of variables disclosed the difference to be insignificant. Each bag that contained large gravel had a higher percentage of mortality due to crushing of eggs. It was apparent that when the area surrounding the eggs was filled with the larger gravel, though the difference was slight, there was a higher percentage of crushed eggs.

Natural Stream Comparison

Placing eggs in a natural stream section established under natural conditions an additional reference for the efficiency of the plastic bag as a retaining agent, as well as a reference for egg mortality due to injury from a given type of gravel. A section of Warm Springs River in Oregon, about 0.5 mile upstream from U. S. Highway 26, was chosen for this study. One hundred eggs were put in each of 4 plastic bags containing gravel from the natural riffle in which they were planted (figures 7 and 8). The bags were put in the river bed on December 17, 1952, about 12 feet from shore in water about 10 inches deep. The eggs were 77 days old. Surface velocity of the water was slightly less than 2 feet a second. Observations were made at various times; in this section of stream the water was always clear. The size of the gravel in the riffle ranged from 8 inches to fine sand. Figure 9 shows size of gravel used in the bags and the newly hatched fry.

FIGURE 7.--Section of Warm Springs River, looking upstream, showing location of egg planting.

FIGURE 8.--Same, looking downstream.

FIGURE 9.--Gravel and newly hatched fry from Warm Springs River.

The bags were taken from the gravel on January 8, 1953. One bag had a hatch of 96 eggs, 2 bags had 99 hatched eggs in each, and the remaining bag contained a 100-percent hatch. These 4 bags, considered collectively, had a 98.5 percent hatch (table 1).

RESULTING DATA AND ANALYSIS

Hatching of Eggs

Gravel Beds. -- For this project, 180 plastic screen bags and 24 screened boxes, each containing 100 eyed eggs approximately 70 days old, were put in the gravel beds on December 10, 11, and 12, 1952. To determine the mortality and hatch during development of the eggs, bags were removed from the gravel for inspection at intervals during the project. For this purpose, bags were removed from the gravel at 76, 79, 83, 90, 93, 97, 100, and 104 days from spawning. At these stages of development the eggs gave hatches of 2, 3, 7, 69, 95, 96, 96, and 96 percent, respectively (figure 10). When the eggs in the samples examined were approximately 97 days old, all that were not injured or dead had hatched.

In order to obtain a clear picture of the maximum percentage of eggs that hatched during the project, it might be well to consider the percentage of hatch obtained between the time the eggs were 97 and 104 days old -- or between the time all eggs not injured or dead in the samples examined were hatched -- and the last time any eggs were removed from the gravel. When all the conditions were considered collectively, there was an average hatch of 96 percent for those eggs removed after the 96th day of incubation.

Tables 2 and 3 present the percentages of hatch obtained under the different sets of variables. These data indicate that the percentage of hatch was essentially the same under all conditions. Comparison of the different sets of variables reveals the difference in hatch to be insignificant. The hatch was greater than 93 percent in all instances and was 99 percent in two instances.

A considerable amount of silt collected within the gravel beds and particularly just upstream from the high-velocity pond. This accumulation was due in part to the cleaning of the rearing ponds, in part to a flash flood of the Little White Salmon River in the spring of 1953. An indication of the depth of this material in front of the high-velocity pond may be seen in figure 11. The hatching in both large- and small-gravel beds and the fry emergence in the large-gravel beds seemed satisfactory in spite of the occurrence of this silt problem.

The percentage hatch, as analyzed in the foregoing paragraphs, ignores the fact that there were two types of mortality which might be considered separately (tables 2 and 3). A certain percentage of eggs did not hatch because they were crushed during the handling or while they were in the gravel beds. It is considered entirely possible that, with greater caution used in the handling of the eggs and with protection of the gravel beds, the mortality due to the crushing of eggs could be reduced. This is exemplified in the data for the eggs that were planted in a natural stream section and in the hatchery troughs (table 1). In both these instances, where the speed in planting only 800 eggs was not of prime importance and where no one walked over the beds, the mortality due to the crushing of eggs was less than 2 percent.

FIGURE 10.--Hatch of eggs in samples examined.

TABLE 2.--Hatch and mortality of eggs in bags planted in large gravel

Depth in gravel (inches)	Number[1] and percent	High velocity				Medium velocity				Low velocity				Totals			
		Hatch	Natural loss	Crushed eggs	Total loss	Hatch	Natural loss	Crushed eggs	Total loss	Hatch	Natural loss	Crushed eggs	Total loss	Hatch	Natural loss	Crushed eggs	Total loss
3------	(Number	290	1	9	10	289	0	11	11	286	1	13	14	865	2	33	35
	(Percent	96.7	.3	3.0	3.3	96.3	0	3.7	3.7	95.3	.3	4.4	4.7	96.1	.2	3.7	3.9
6------	(Number	283	1	16	17	281	2	17	19	285	1	14	15	849	4	47	51
	(Percent	94.3	.3	5.4	5.7	93.7	.7	5.6	6.3	95.0	.3	4.7	5.0	94.3	.4	5.2	5.6
12------	(Number	286	2	12	14	290	1	9	10	296	0	4	4	872	3	25	28
	(Percent	95.3	.7	4.0	4.7	96.7	.3	3.0	3.3	98.7	0	1.3	1.3	96.9	.3	2.8	3.1
Totals--	(Number	859	4	37	41	860	3	37	40	867	2	31	33	2,586	9	105	114
	(Percent	95.4	.4	4.2	4.6	95.5	.3	4.2	4.5	96.3	.2	3.5	3.7	95.7	.3	3.9	4.2

[1]/Each category represents 300 eggs planted.

TABLE 3.--Hatch and mortality of eggs in bags planted in small gravel

Depth in gravel (inches)	Number[1] and percent	High velocity				Medium velocity				Low velocity				Totals			
		Hatch	Natural loss	Crushed eggs	Total loss	Hatch	Natural loss	Crushed eggs	Total loss	Hatch	Natural loss	Crushed eggs	Total loss	Hatch	Natural loss	Crushed eggs	Total loss
3------	(Number	296	2	2	4	289	1	10	11	288	6	6	12	873	9	18	27
	(Percent	98.6	.7	.7	1.4	96.3	.3	3.4	3.7	96.0	2.0	2.0	4.0	97.0	1.0	2.0	3.0
6------	(Number	285	0	15	15	289	1	10	11	293	1	6	7	867	2	31	33
	(Percent	95.0	0	5.0	5.0	96.3	.3	3.4	3.7	97.7	.3	2.0	2.3	96.3	.2	3.5	3.7
12------	(Number	287	2	11	13	291	1	8	9	289	1	10	11	867	4	29	33
	(Percent	95.7	.7	3.6	4.3	97.0	.3	2.7	3.0	96.3	.3	3.4	3.7	96.3	.4	3.3	3.7
Totals--	(Number	868	4	28	32	869	3	28	31	870	2	31	33	2,607	15	78	95
	(Percent	96.4	.4	3.2	3.5	96.5	.3	3.1	3.4	96.7	.9	2.4	3.3	96.6	.5	2.9	3.4

[1]/Each category represents 300 eggs planted.

FIGURE 11.--Debris and silt accumulation: high-velocity pond.

Emergence

The last of the bags containing eggs was removed on January 16, 1953, though, as previously stated, no live eggs were found in the bags recovered on or after January 6. After January 6, the screened boxes were checked periodically to determine the first emergence of fry. This occurred on February 2 in the three beds of small gravel.

The percentage of fry which emerged from the beds of small gravel was quite low. There were 1,200 eggs planted in the boxes in the small gravel, and only 158 (13 percent) fry emerged. There was no emergence of fry in 4 of these boxes in small gravel. The eggs were planted at 4 different depths below the gravel surface, and a small percentage emerged as fry in each case from one pond or another. From 300 eggs planted 18 inches below the gravel surface, 3 fry (1 percent) emerged. From the eggs planted at 12, 6, and 3 inches, there emerged 7, 49, and 99 fry, which represented 2, 16, and 33 percent, respectively. From the plantings made in the high-, medium-, and low-velocity ponds, the fry which emerged numbered 4, 53, and 101 (1, 13, and 25 percent), respectively.

The percentage of emergence was considerably higher from the large-gravel beds than from the small-gravel beds. There were 1,200 eggs planted in large gravel within screened boxes, and 1,027 (87 percent) of these hatched and emerged as fry. From the eggs which were planted 18, 12, and 3 inches below the gravel surface, there emerged 256, 255, and 253 fry, representing 85, 85, and 84 percent, respectively. The highest percentage emergence was obtained from those eggs planted 6 inches below the gravel surface. From these eggs there emerged 263 fry (88 percent). From the high-velocity pond came 323 fry (81 percent). From the medium-velocity pond came 350 fry (88 percent). The best results were obtained

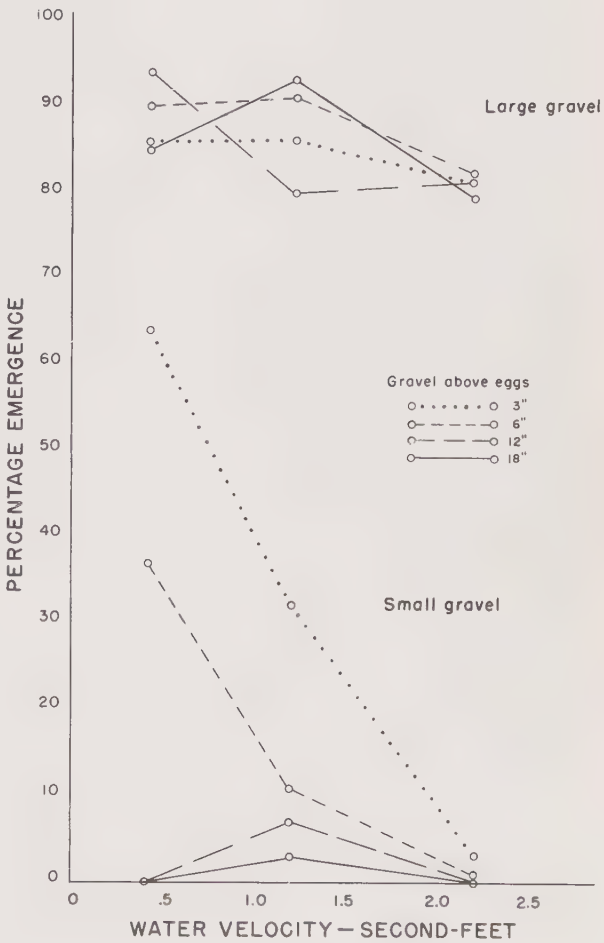

FIGURE 12.--The emergence of young from gravel beds.

from the low-velocity pond, where 354 (89 percent) of the planted eggs emerged as fry.

The fry that first emerged from the large gravel on February 10 were about 36 days old. The age is considered in days from the date when all eggs in the samples examined, not injured or dead, were hatched (96 days from spawning). When the fry were approximately 93 days old (April 7), 50 percent or more of the fry had emerged from the large gravel, with the exception of a screened box in the high-velocity pond. The emergence of fry continued until May 18, when the fish were approximately 133 days old. It appears, therefore, that at least some of the fry had remained in the gravel a little more than 4 months after hatching. All of the fry that had emerged from the gravel by February 17, 1953, had some portion of the yolk sac visible. On this date 1 fry had no yolk sac visible from a side view and only a small opening in the abdominal wall was visible from a ventral view. By March 10, when the fry were 64 days old, approximately 50 percent of the fry that emerged still had a slight yolk sac showing. Only 10 percent of the fry that emerged 2 days later had a visible yolk sac. When the emerged fry were 95 days old, only 2 out of 150 had a visible yolk sac and only 1 had an unsealed abdominal wall. The remaining fry emerged with the abdominal wall completely closed. The first fry that emerged from the gravel were about 1.25 inches long, and by the time the last had emerged they were about 1.75 inches long. Table 4 gives the percentage emergence and corresponding age of fry in screened boxes from the large-gravel beds. Figure 12 is a graph showing the percentage emergence from the three ponds.

Subsurface Flow Measurement

After all the fish had emerged from the gravel, the flow of water through the gravel was studied by introducing a solution of sodium chloride in the upper end of the pond and measuring the lapse of time before a change in the conductivity of the water could be detected downstream. A sodium chloride solution (2,600 parts per million) was introduced into the gravel at depths of 4 and 23 inches below its surface. A record was then made of the time required for the sodium chloride solution to affect a reading on a voltmeter for a given set of electrodes. For convenience, reference is made to electrode sets as Nos. 1 through 5. The set nearest to the surface of the gravel is No. 1. No. 5 represents 2 separate rods acting as a set of electrodes on the bottom of the pond (figure 3). The results obtained at 24 stations where observations were made may be seen in table 5.

TABLE 4.--Percentage emergence and corresponding age of fry

Date	Age (days)	Percentage emergence in screened box numbered--											
		2	3	6	8	9	12	14	15	18	20	21	24
2-10	36	9	0	0	0	0	0	0	0	0	0	2	0
2-13	39	18	1	0	0	0	0	0	0	0	0	2	0
2-17	43	18	1	0	0	0	0	0	0	0	0	3	0
2-24	50	19	3	0	0	0	0	0	1	0	7	3	0
2-27	53	19	3	0	0	0	0	0	1	0	7	6	1
3- 4	58	20	3	0	1	0	0	0	3	0	9	9	1
3- 6	60	20	5	0	1	0	0	0	5	0	9	10	1
3-10	64	21	6	0	1	1	0	2	6	0	10	11	9
3-12	66	21	7	0	1	2	0	4	7	0	10	11	23
3-20	74	21	7	0	2	2	0	4	8	0	15	11	23
3-23	77	21	7	0	11	2	0	10	10	0	61	13	29
3-26	80	21	7	0	17	2	0	26	15	0	67	24	35
3-30	84	24	7	15	36	2	0	58	26	16	77	32	44
4- 7	92	41	61	53	56	57	84	78	71	65	81	67	71
4-10	95	69	84	61	67	70	94	80	88	84	81	78	83
4-14	99	77	91	67	75	73	94	82	90	89	81	85	85
4-17	102	78	91	73	76	79	94	82	91	89	81	86	86
4-24	109	78	92	78	81	80	94	82	91	89	81	86	86
5- 1	116	79	93	83	81	80	94	82	91	90	81	86	86
5- 8	123	79	93	84	81	80	94	82	91	90	81	86	86
5-18	133	79	93	85	81	80	94	82	91	90	81	86	86

In all instances a downstream movement of water was detected near the bottom of the gravel. Most often the movement of water was faster in the downstream end of the gravel beds than at the upstream end. The time required for the sodium chloride solution to move 1 foot downstream increased from the high-velocity to the low-velocity pond. In the high-velocity pond the subsurface velocity range was from 0.1 to 0.03 foot per second, while in the low-velocity pond this range was from 0.03 to 0.001 foot per second. In all 3 ponds, the fastest movement of the sodium chloride solution over the test distance of 1 foot was 0.1 foot a second, and the slowest was about 0.001 foot a second. The overall picture of the subsurface velocity is not clear because of the inadequacy of the method of measurement. Thus, a downward movement of water from the area just below the gravel surface toward the bottom of the gravel was indicated everywhere but in the middle section of the low-velocity pond. Near the upstream end of the large-gravel beds there was a horizontal movement of water near the gravel surface in all the ponds. A similar movement was seen near the downstream end of the large-gravel bed in the medium-velocity pond. Movement in this same area near the upstream end in the small-gravel beds was evident only in the medium-velocity and low-velocity ponds, and downstream only

TABLE 5.--Water velocity measurements in gravel beds

D.E.	Subsurface flow in feet per second in--							
	Large gravel				Small gravel			
	U.S.	U.M.	D.S.	D.M.	U.S.	U.M.	D.S.	D.M.
High velocity pond								
4 - 1	0.083	----	----	----	----	N	----	N
4 - 2	.071	N	----	N	N	N	----	N
4 - 3	.067	N	----	.050	N	N	N	N
4 - 4	.040	.050	----	.056	.029	.031	.045	.077
4 - 5	.059	.040	.083	.059	.025	.030	.059	----
23 - 3	.050	N	----	----	----	N	----	----
23 - 4	N	.067	----	.050	N	N	----	N
23 - 5	.050	.050	.100	.059	N	.033	.100	.100
Medium velocity pond								
4 - 1	.100	N	N	.100	.100	.100	----	----
4 - 2	.071	N	N	.077	.067	.050	----	----
4 - 3	.038	.056	.042	.050	N	.033	N	----
4 - 4	.027	.053	.045	.029	.013	N	N	N
4 - 5	.030	----	----	.020	----	.007	.010	.018
23 - 3	N	N	.037	N	----	----	----	----
23 - 4	.100	.059	.059	.026	N	N	N	----
23 - 5	.050	.045	.083	.028	.013	.008	.011	.025
Low velocity pond								
4 - 1	.050	Inc.	----	----	N	.033	Inc.	----
4 - 2	Inc.	Inc.	----	N	Inc.	.013	Inc.	----
4 - 3	Inc.	Inc.	N	N	Inc.	.005	Inc.	----
4 - 4	Inc.	.050	.006	----	.001	.008	.003	----
4 - 5	----	Inc.	.005	----	----	----	----	----
23 - 3	Inc.	.013	----	N	----	----	----	.005
23 - 4	Inc.	.029	----	N	----	N	----	.005
23 - 5	.029	.029	.002	.002	.003	.003	.003	.005

D.E. : First column is depth of insertion of sodium chloride solution, and second column is the designated number of set of electrodes located 12 inches downstream.
U.S. : Station near upstream end and side of gravel bed.
U.M. : Station near upstream end and middle of gravel bed.
D.S. : Station near downstream end and side of gravel bed.
D.M. : Station near downstream end and middle of gravel bed.
N : No reading was obtained on the voltmeter.
Inc. : Increased reading obtained, but no time recorded.
---- : No test was made.

in the low-velocity pond. The results also indicated an upward movement of water near the upstream end of the large-gravel beds in the high- and low-velocity ponds and a similar movement at the downstream end in the medium-velocity pond. An upward movement was seen near the downstream end of the small-gravel bed only in the low-velocity pond.

SUMMARY

From early in November 1952 to early in July 1953, the planting and hatching of chinook salmon eggs in gravel was studied to determine its value as a tool of fishery management in the Columbia River area.

Spawning and rearing ponds at the U. S. Fish-Cultural Station on the Little White Salmon River near Cook, Washington, were used to set up artificial gravel beds in which chinook salmon eggs could be planted. The temperature, velocity, and volume of water flowing through the gravel beds were observed and recorded. Plastic screen bags containing salmon eggs were planted in various depths and sizes of gravel. From these bags, removed at periodic intervals, were determined the hatch and mortality of the eggs. Boxes made of wooden frames and plastic screen were also planted in gravel and examined regularly to determine the rate of emergence of fry that hatched from the eggs placed in the boxes.

Controls were set up to determine the efficiency of the plastic bags as retaining agents, the effect of a given type of gravel surrounding the eggs with reference to mortality, and the results from eggs placed in the same type of plastic bag and planted in a natural stream.

The average hatch for the eggs planted under different sets of variables in the gravel was 96 percent. Comparison of these variables reveals that the difference in percentage hatch is insignificant. (It is considered possible that the mortality caused by crushing of eggs could be reduced and the percentage hatch thus increased proportionately.)

The mortality of the planted eggs was divided into two categories: (1) that caused by the crushing of eggs, and (2) that which resulted from unknown causes (primarily percolation).

In the hatchery troughs the total mortality was 2.3 percent, 2.0 percent being caused by the crushing of eggs and 0.3 percent resulting from unknown causes. The eggs planted in Warm Springs River sustained a mortality of 0.5 percent, half of it resulting from unknown causes.

In the gravel beds the mortality due to unknown causes was essentially the same under all the various conditions, as was the percentage hatch under the same conditions.

In the beds of small gravel only 13 percent of all the eggs emerged as fry, but 87 percent emerged in the large-gravel beds. By the time the fry were approximately 92 days old (considered from the date all live eggs in the samples were hatched), with the exception of 1 box, 50 percent or more of all fry had emerged from the large-gravel beds. The highest percentage emergence from the large-gravel beds was obtained from the eggs planted 6 inches below the surface of the gravel and the eggs planted in the low-velocity pond.

The percolation or movement of water within the gravel ranged from 0.1 to about 0.001 foot per second. This movement progressively increased from the low- to the high-velocity pond. A velocity as low as 0.001 foot per second was evidently satisfactory for the hatching of chinook salmon eggs, and a satisfactory percentage emergence of fry was obtained where the subsurface water velocity was as low as 0.002 foot per second.

Correlation of these velocity measurements with hatching of eggs indicates that chinook salmon eggs will hatch and young fry will emerge from gravel when the water velocity within the gravel is as low as 0.002 foot per second.

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COMMENT

State of Illinois
DEPARTMENT OF CONSERVATION

706-1/2 Locust
Sterling, Illinois
August 18, 1954

Editors, The
Progressive Fish-Culturist
Fish and Wildlife Service
Interior Building
Washington 25, D. C.

Dear Sirs:

I have read Mr. Dave Elder's report, in the past July issue of The Progressive Fish-Culturist, on the reproduction of fish subjected to electric current.

I 'shocked' 15 smallmouth bass (1-1/2 to 3 lbs.) from the Rock River at Sterling, Illinois, on May 21, 1954. The fish were in good condition when they were put in a 1/5-acre abandoned gravel pit with a maximum depth of 5 feet which was rotenoned last spring.

On July 6, 1954, a short seine haul revealed many young-of-the-year smallmouth bass.

The electric power source was a Homelite gasoline motor-driven generator supplying a 1,000-watt 120-volt alternating current.

This is another case where the fish did not become sterile when subjected to an alternating electric current.

Very truly yours,

Rudy Stinauer
District Fisheries Biologist
of Northwestern Illinois

AN INJECTION METHOD FOR MARKING CRAYFISH

Keith V. Slack
U. S. Navy Hydrographic Office
Washington, D. C.

A METHOD OF PERMANENTLY marking individual crayfish or groups of crayfish would greatly facilitate the collection of field data on mortality, movements, and age and growth of these important fish-food organisms. Previous workers have removed all or parts of the abdominal appendages as a marking method (Svärdson 1949). The disadvantages of that work are that such marks are temporary because of rapid regeneration, and that mutilation might alter the behavior of the crayfish. Penn (1943) used celluloid fish tags on crayfish kept in a concrete pool. Another method has consisted of attaching a small metal tag to the posterior segments (see discussion after Langlois' paper, 1937). Rounsefell and Everhart (1953) illustrated methods of marking lobsters by attaching tags to a band encircling the carapace or extending from the rostrum to the telson. A barb tag for lobsters is also described. All such mechanical tags either interfere with molting or are lost with the exuviae. For these reasons a different approach was sought.

Hickling (1945) described a procedure for marking fish with a tattoo needle, and this suggested the possibility that a sub-exoskeletal injection of a colored material could be developed for tagging crayfish. Preliminary trials indicated that the thickness and pigmentation of the exoskeleton in most regions of the body prevent a colored mark from being observed easily. However, the ventral surface of the abdomen is covered by a thin, transparent cuticle through which marks are quite visible. Injection into the muscles of the abdomen or appendages invariably resulted in paralysis followed by death. For this reason, the mark was injected just beneath the shell and to one side of the median ventral nerve cord. In most instances, injections were made with a 2-milliliter hypodermic syringe and a No. 23 needle. Crayfish having a cephalothorax length greater than 12 millimeters were easily marked by this method. For heavy liquids, a makeshift syringe was constructed from a medicine dropper by cutting off the small end and attaching a hypodermic needle with a short length of rubber tubing. The marking substance should have the following properties: it should be nontoxic, distinctively colored, and must not spread through the blood sinuses or adhere to the exuviae. A variety of colored materials, both liquid and solid, were tried on specimens in laboratory tanks (table 1). In general, liquids immiscible with water do not spread in crayfish blood, and solid substances tend to adhere to the shed shell. The most successful of the materials tested here was black Bates Numbering Machine Ink (No. 4929A). Colored numbering-machine inks are obtainable but were not tested. Our limited experience indicates that they should prove satisfactory.

The following marking procedure has been adopted. The specimen is held in the left hand, ventral side up and the posterior end facing the operator. The needle is inserted to one side of the midline in the third or fourth segment from the end of

Contribution No. 564 from the Department of Zoology, Indiana University.

the abdomen and then pushed forward just beneath the exoskeleton. When the needle point is completely free in the sinus, the material is injected as a discrete spot about 1/8 inch in diameter between the cutible and the muscle. Different marks would be made possible by varying combinations of color and position of the mark.

The successful Bates ink was obtained shortly before the work had to be discontinued; so extensive laboratory experiments were not performed. However, the material was tested under field conditions.

Field Experiment

In May 1951, 55 crayfish (Orconectes propinquus) were collected from a pond at the Maxinkuckee Experiment Station in northern Indiana and were marked with black Bates ink. They were returned to the pond after being marked. The spring molt had not yet taken place, and most of the females that had a cephalothorax length greater than 19 millimeters were carrying eggs. Of 566 crayfish collected when the pond was drained 6 months later, 7 individuals (12.7 percent of the marked crayfish) were recaptured. Only a part of the crayfish population was recovered. This was due to the burrowing habits of the crayfish and to the presence, on the pond bottom, of a thick mat of Chara, which retained many more. In addition, many of these crayfish were young-of-the-year that could not have been marked in May.

Individuals could not be distinguished, but the sizes of recaptured crayfish indicated that growth, and therefore molting, occurred in the interval between marking and recapture (table 2). Van Deventer (1937) found an average size increment of 2.4 millimeters per molt for this species in Illinois. On that basis, the 42-millimeter male must have molted at least twice. For the other crayfish listed here, a minimum of 2 molts is indicated, although the exact amount of growth cannot be determined from the data. If it be assumed that the recaptured individuals had molted only 1 or 2 times and had consequently grown 2 to 5 millimeters in cephalothorax length, all must have measured more than 30 millimeters in May. This would be a recapture of 58.3 percent of the larger group, which is probably too high when natural mortality and probability of recapture are considered. Therefore, it appears likely that these recaptured

TABLE 1.--Summary of tests of materials and methods for marking crayfish

Material	Method of application	Results
Carmine in water	Injection	Spread, faded.
Permanent ink (blue)	----do	Do.
India ink (black)	----do	Do.
Liquid latex (red, yellow, blue, and mixtures).	----do	Spread, faded slowly. Deposited in gills.
Textile paint (yellow)	----do	High mortality. Unable to shed successfully.
Day-Glo Poster Paint (various colors).	----do	High mortality. Spread.
Bates Numbering Machine Ink (black, No. 4929A).	----do	Formed discrete spot.
Thin rubber strips	Pushed under shell with needle.	Adhered to exuviae at molt.
Solid latex pellets	----do	Do.
Glass beads	----do	Do.
Glass bead on barbed wire	Barbed ends inserted in abdominal muscles.	Produced paralysis followed by death.

animals had molted more than once. The fact that the mark could be recognized indicates that repeated molting during 1 growing season did not affect the quality of the mark. Moreover, 1 of the marked and recaptured crayfish from this experiment shed in the laboratory 1 year after it had been marked. There was no apparent diminution of the mark.

TABLE 2.--Comparison of the sizes of marked and recaptured crayfish, Maxinkuckee Experiment Station, Indiana

[Marked on May 3, 1951; recaptured on October 17, 1951]

Length of cephalothorax (mm.)[1]	Males		Females	
	Number marked[2]	Number recaptured	Number marked[2]	Number recaptured
30	1			
31	2		1	
32	1		1	
33			2	
34			1	
35		1	1	
36	1			
37	1	1		1
38		1		2
39				
40				
41				
42		1		
Total	23	4	32	3

[1] This measurement is approximately one-half of the total length.

[2] Not shown are 17 males with cephalothorax lengths ranging from 13 to 26 mm.; 26 females with cephalothorax lengths ranging from 15 to 29 mm.

Discussion

Investigation of the rate of growth of crayfish has generally been by size-frequency distributions. Variability of growth rate, however, leads to difficulty in distinguishing age classes by the end of the growing season. A more accurate determination of the growth, age at maturity, length of life, and mortality would be possible by study of a population of crayfish marked soon after they became free-living. A check on horizontal movements could be made by using different marks in different areas. In addition, this method may have application to the study of certain marine crustaceans such as lobsters and crabs.

Acknowledgment

Sincere appreciation is expressed to Dr. Shelby D. Gerking, under whose direction this study was conducted.

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A SIMPLE TRAP METHOD FOR RESCUING FINGERLING SALMONIDS

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THE RUNOFF PATTERN of many north-coastal streams in California is such that a large loss of fingerling salmonids frequently occurs during the dry summer period. In a poor water year this can amount to virtually the whole year's production over much of the area. The California Department of Fish and Game has attempted to alleviate this problem by maintaining fish-rescue crews on the streams during the critical periods. Several county governments--notably those of Mendocino, Sonoma, and Del Norte Counties--have assisted in the program by providing additional personnel with their share of the fish and game fine monies. An average of 734,148 trout and salmon have been rescued each year since 1944.

The usual method of rescue has been to net fish from drying streams and transport them to dependable waters in the same drainage. This method of rescue usually proved adequate except for very small rocky streams that dry up entirely each summer yet support a flow sufficient to make them attractive to steelhead and silver salmon spawners each fall and winter. There is nearly always an escapement of early emerging fry, but the larger part of the hatch is lost each year. These streams stop flowing in the lower reaches first, the flow continuing in the upper sections about a month longer. Because of their shallow character, the uneven cobble bottom, and the algal growth, only a very small portion of the trapped salmonids can be rescued by the usual seining methods.

(Photograph courtesy of the authors)

The trapped fingerlings continue their nocturnal migration downstream even though there is no chance for them to move out into the main stream. Rescuers have taken advantage of this by visiting the lowermost holes periodically and seining the trapped fish. This takes considerable time, and many fish are missed. An electric shocker was little more effective

This work was performed as part of Dingell-Johnson Project California F-2-R, "A Study of Catfish Fishery of California."

than the seine where it could be used, and often was totally ineffective because the character of the stream prevented use of efficient electrodes and capturing devices. It was also too awkward to move from stream to stream.

The junior author, then in charge of a fish-rescue crew, noted the nocturnal downstream migration of the fish and devised a simple yet efficient method of rescuing salmonids from this sort of situation. He first seined all the fish that could be taken from the dry lower end upstream to a point just above the first good pool that still had a flow into it. A small dirt-and-rock dam, usually only a few inches high, was then constructed to divert the whole flow of the stream above the pool through a 4-inch pipe into a wire live car set in the pool (see figure). Each night all the fingerlings that were moving downstream from above this point passed through the pipe into the live car and were removed in the morning by the crew. A protective lid was placed on the live car to exclude predators.

The trap method permits nearly all fish to be saved, and use of this method permits the working of about five times as many streams as can be worked with seines. In 1952 one crew, using the trap method, rescued 24,182 steelhead and 7,313 silver salmon fingerlings from several small streams (see table). In 1951 this crew, using seines, had rescued only 2,250 steelhead and 3,475 silver salmon from the same streams. Although differences in runoff pattern may have played some part in the tenfold increase in numbers of fish rescued, the change in method is believed to have been largely responsible.

The live cars were made of 1/8-inch hardware cloth, reinforced in the corners with 1- by 1-inch 20-gauge steel angles. A rectangular frame of 1/2-inch split tubing made the top of the trap rigid. The steel angles at the corners and the clips attaching the split tubing to the top were punched and riveted to the hardware cloth.

The largest live car was 2 feet wide, 3 feet long, and 2 feet deep; the others were successively graduated 1 inch less in all dimensions to allow the nesting of a series. These live cars were lighter in weight, more compact, and easier to maintain than the conventional wooden-framed live cars.

The pipe that was used to divert the flow of the stream into the trap was a 28-gauge conductor, 10 feet 4 inches in diameter, crimped on one end to allow joining of 2 or more lengths.

Fish rescued by trap from tributaries of Ten Mile Creek, Mendocino County, in 1952

Stream	Inclusive dates of operations		Rescued fish			
			Steelhead		Silver Salmon	
	From	To	Number	Size (No. per oz.)	Number	Size (No. per oz.)
A---------	May 8	June 4	22,532	42 - 65	2,735	18 - 30
B---------	May 15	May 16	1,000	50	500	20
C---------	May 5	May 6	650	65	450	30
D---------	June 5	June 19	0	0	3,628	20 - 24
Total---	-------	-------	24,182	----------	7,313	----------

"Common-sense minnow seines last much longer," reports C. E. Cozort, superintendent of the U. S. Fish-Cultural Station at Tishomingo, Oklahoma, "when they have been dipped in a rubber-base latex paint. The paint is more pliable than tar."

A MODIFICATION OF THE KEMMERER WATER BOTTLE FOR SAMPLING SHALLOW WATERS

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Missouri Conservation Commission
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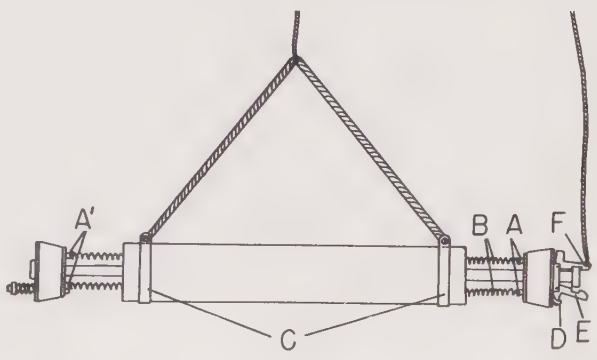
MOST FISHERY INVESTIGATORS are concerned about the accuracy of their methods of sampling water. Variations of the Kemmerer, siphon, and bottle-train methods are satisfactory for the deeper waters. Sampling water less than 3 feet deep is beyond the limitations of most devices.

The need for a sampling method at precise depths in shallow water became apparent in setting up a study of the water chemistry of ponds. Dissolved oxygen, alkalinity, pH, and nutrients in ponds differ with small changes in depth. A Kemmerer water sampler was modified to meet the requirements of this study by Ted Fisher[1] and the author. It is believed that this modification is satisfactory for obtaining water samples at various depths for the detection of these chemical variations.

The Kemmerer water sampler was modified as follows (see figure): The chains were removed from the anchoring pins (A) at the upper stopper. Two similar pins (A') were installed in the lower stopper. Two screen-door springs (B) were attached to the upper stopper (replacing the chains), run through the sampler, and then fastened to the lower stopper. The springs were adjusted with sufficient tension to hold the stoppers firmly together in the closed position. To manipulate the sampler in depths beyond arm's reach, a method of suspension was also improvised. Two metal straps (C) were secured at each end of the barrel, and a rope bridle was attached. The trip mechanism was also altered by pulling the lower leaf spring (D) out and over the lower trip lever (E). This prevents the lever from acting as a catch. The lower lever might be removed, but this would prevent use of the sampler in the vertical position. A hole was bored in the distal end of the upper trip mechanism (F), and a desired length of cord was attached through this hole and to the rope bridle as shown. A sharp jerk on the cord will release the catch and close the bottle.

To obtain a true sample, one must be sure that the sampler is flushed of water accumulated when the bottle is lowered to the desired depth. This may be done in a stream by allowing the current to displace the water. In ponds or lakes, flushing is done by moving the sampler laterally for several yards at the desired depth.

(Drawing courtesy of the author)



[1] Mr. Fisher was formerly with the Missouri Conservation Commission.

DIVIDENDS FROM RESEARCH

THE BIRTH OF A FISHERY

Donald L. McKernan
U. S. Fish and Wildlife Service
Honolulu, Hawaii

Organized as the Pacific Oceanic Fishery Investigations, a unit of the U. S. Fish and Wildlife Service with headquarters in Honolulu, we have been investigating the potential fishery resources of the central Pacific, an area of nearly 7 million square miles, from approximately 30° N. to 10° S. latitude and from 110° W. longitude to 180°. Our efforts have been concentrated on locating pelagic, oceanic areas with favorable conditions for biological productivity and systematically searching such areas for concentrations of fish.

Two research methods are being used to attain those objectives. First, we have depended upon biological and physical oceanography to define the regions of potential productivity. The movement of major water masses, including current boundaries, vertical motion, and measures of inorganic nutrient salts in the sea--all have provided clues to areas of high biological productivity. Second, after finding promising environments in the open sea, we have sampled the fish populations, using accepted commercial fishing techniques as well as the biological sampling methods necessary for capturing the smaller, more elusive fishes.

Using these methods, we have found evidences of upwelling associated with a divergence at or near the Equator about 1,200 miles south of Hawaii. This upwelling enriches the euphotic zone by bringing up inorganic salts from the deeper waters. Plankton and midwater trawl samples, when compared with similar samples from other pelagic tropical waters, contain unusually large amounts of organisms. Experimental fishing by various means demonstrated the existence of an extensive concentration of yellowfin tuna, its center of abundance lying in a band from about 140° to 170° W. longitude and from 5° N. latitude to the Equator, an area of about 500,000 square miles.

Though we find the longline method of fishing successful for sampling yellowfin, only an occasional skipjack is taken by this gear; however, our studies of tuna eggs and larvae convince us that, in addition to the abundant yellowfin, skipjack are present in even greater numbers.

We are now encouraging the development of a commercial fishery. This past spring two West Coast fishing boats took 210 tons of yellowfin tuna from the Line Islands region near the Equator while using the longline method of fishing. At this writing /August 1954/ three more Pacific Northwest boats are longline fishing in that region. Here, the discovery and the early exploration of these fishing grounds are nearing an end and the birth of a new fishery is in progress. The success or failure of this new fishery will depend on whether or not American fishermen can profitably harvest the tuna in the new area while using an unfamiliar type of gear, the Japanese longline. The gap between the completion of successful research and the firm establishment of a profitable commercial fishery is difficult to bridge; it will be interesting to see whether the central Pacific tuna fishery will provide one of the rare examples where this transition has been successfully effected.

Although the potential yield from this newly discovered resource is unknown, a comparison of the area of this vast belt

along the Equator with the area used by the present American fishery off Mexico and central America (which supports a $125,000,000 industry) indicates a likelihood that full utilization of the tunas from the central Pacific would produce a like amount.

We believe that there are other regions in the tropical and subtropical Pacific Ocean which, because of unique oceanographic conditions, will prove unusually productive of fish. For example, islands jutting up from the bottom of the ocean and interrupting the flow of major currents apparently cause enrichment of surrounding surface waters. Also, north of the Hawaiian Islands at the boundary between the easterly-flowing North Pacific Drift and the westerly-flowing North Equatorial Current is a region of turbulence and eddies which shows promise of prodigious biological productivity. Investigations are now under way to find and chart these favorable environments and to evaluate their potential fishery resources.

WARM-WATER FISHING REGULATIONS

Kenneth E. Christensen
Michigan Department of Conservation
Ann Arbor, Michigan

Size limits on pan fishes were abolished in September 1949 on all lakes in the State of Michigan. The closed season on bluegills and sunfish was shortened to a few days in April in 1952 and was abolished entirely in 1954.

Whereas all lakes had been closed to fishing during the spring months from 1929 through 1945, this law was made to apply to only 30 counties and parts of 4 others in the southern part of the State in 1946 and all lakes in the State were opened to spring fishing in 1952. Thus much additional fishing and a greater harvest of fish were realized.

Prior to 1949, it was believed that warm-water lakes were being overfished and the size limit on pan fish was for the purpose of giving protection to spawning stocks. Also, until 1946, the State had carried on an intensive planting program to "restock" the "depleted" lakes. Extensive research performed by Michigan and other States demonstrated conclusively that the pan fishes were prolific enough to overstock lakes without aid from rearing ponds. Plantings of most warm-water fishes for maintenance were discontinued in 1946; excepted were limited plantings for experimental purposes.

The Fish Division established experimental fishing regulations on 12 lakes in 1946 to test the effect of year-round fishing. Six of the 12 lakes were opened to year-round fishing for all the pan fishes except bluegills and sunfish; while the other 6 lakes were opened to the taking of all pan fishes, including bluegills and sunfish. Two of the 6 lakes opened to year-round fishing for all pan fishes had the added provision of no size limit on the pan fish and no creel limit on pan fish that were less than 6 inches long. These 2 lakes had populations of very slow-growing pan fishes. A creel census was conducted on these 12 lakes during the 5 years (1946-50) that the regulations were in effect. The creel census was conducted on a sampling basis which included a means of estimating total fishing for spring, summer, fall, and winter seasons. The index of fishing quality that was used to compare seasonal and yearly catch data was the catch per hour per fishing trip.

The conclusions drawn from this study were that size limits were not needed on pan fishes, and that lakes throughout the State could be opened to year-round fishing for all pan fishes. Without such definite and conclusive evidence, the legislature would not have enacted this legislation, nor would the public have accepted the change.

The creel census has been continued on several of the 12 lakes. New experiments in changing regulations were begun in 1954; these dealt with northern pike, walleye, and largemouth and smallmouth bass.

THE WALLEYE PROBLEM IN GREEN BAY

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The walleye normally makes up a relatively unimportant part of the commercial production of fish in the Michigan waters of Green Bay. From 1929 (when modern statistical records began) through 1945, the annual take did not exceed 108,000 pounds, fell as low as 16,000 pounds, and averaged only 49,000. The catch was poor in 1945 (only 21,000 pounds), but even then reports of enormous numbers of small walleyes gave portent of the unusual events to come. The catch rose to 72,000 pounds in 1946, to 262,000 in 1947 (the highest figure since 1897), and to new highs of 572,000 in 1948, 1,063,000 in 1949, and 1,294,000 in 1950. Statistical analyses conducted annually by the U. S. Fish and Wildlife Service proved the increased take to be the result of a sharp rise in the abundance of walleyes and a greatly increased fishing pressure. Age analyses indicated that the great bulk of the fish--as much as 90 percent, and more in the more productive years--came from a single year-class, hatched in 1943.

The great abundance and production of walleyes in northern Green Bay led almost immediately to dissension among three groups--local commercial fishermen, commercial fishermen who came to Green Bay from other ports, and a group of anglers and resort owners who united to form a "Walleye Protective Association."

The anglers and especially the resort owners who had expanded facilities greatly as northern Green Bay suddenly developed a national reputation for walleye fishing, viewed the high commercial production as wanton destruction certain to lead to ruin; they believed just as firmly that imposition of drastic restrictions on commercial fishing would perpetuate the abundance of walleyes that they found so pleasant. Acting on these views, they framed and had introduced in the Michigan legislature a bill containing provisions that would have crippled the fishing industry of the area.

In the midst of this controversy, biologists of the Service were asked to give evidence and present opinions at a public hearing in Escanaba, Michigan, in October 1950, and before the Fisheries Committee of the Michigan House of Representatives in March 1951. The testimony stressed the following points: reproduction of walleyes as phenomenal as that in 1943 was without precedent and most unlikely to occur again within the near future; a return from high levels of abundance and production toward normal conditions was surely to be anticipated (the catch did subsequently fall, as predicted, to barely 500,000 pounds in 1951 and to less than 300,000 pounds in 1952); the utilization of the large crop of walleyes was desirable from both an economic and a biological standpoint; the 1943 year-class came from a relatively small spawning stock, and the presence of great numbers of spawners cannot assure high reproduction and may even restrict it; the proposed restrictive regulations offered no promise of benefit to angling but certainly would impose economic hardship on commercial fishermen and deprive the community of an important source of income. The restrictive legislation failed to pass; the changes made constituted fair, reasonable adjustments to ease locally troublesome situations.

At the laboratory recently established by the U. S. Fish and Wildlife Service at Fort Myers, Florida, Gymnodium brevis, the red-tide organism, has been cultivated artificially for the first time. Even if red tide disappears, as it did after the 1947 outbreak, research can be continued to determine what chemical compounds are most effective control agents, what levels of concentration are best, and what combinations of hydrographic and meteorological factors are essential to rapid propagation of the organism.

NORTH AMERICAN FISH POLICY

The American Fisheries Society
Eighty-fourth Annual Meeting, September 13-18, 1954
Seattle, Washington

TO STRENGTHEN THE PURPOSES AND TO ACHIEVE THE OBJECTIVES OF THE AMERICAN FISHERIES SOCIETY, the following policy is adopted:

I. State, National, and International Relations. The individual States should be responsible for the administration and management of the fisheries within their respective boundaries and should perform, by agreements, these functions for inter-State fisheries.

The Federal Governments, in addition to fulfilling their responsibilities for the administration of laws pertaining to national, territorial, and international fisheries, should collect and disseminate information on fisheries and should serve in an advisory capacity to the States and Provinces on fishery problems.

Where two or more nations share a fishery, rational management should be secured by means of a multilateral approach and international agreement. In promulgating these treaties the signatory nations should take into account the research and conservation measures undertaken by the component States and Provinces.

II. Administration of Fisheries. Fisheries should be administered on a non-political basis and by individuals trained and experienced in the scientific management of fisheries. Biological facts should receive primary consideration in the utilization of fish stocks. The agency charged with the administration of the fisheries should be responsible for establishing needed regulations.

Public access to sport fisheries is of paramount importance. Present public ownership of water frontage should be jealously guarded and should be expanded at every opportunity.

Conflicts between sport and commercial fisheries should be settled on the pertinent facts in each case. In many instances waters will support both types of fisheries with mutual benefit. Where actual competition exists to the proved detriment of either fishery, an objective economic appraisal should form the basis for the determination of proper regulations.

III. Research. The success of any fish-management policy, in private or in public waters, is in proportion to its basis on factual information. This is a clear demonstration of the prior requirement for research in all phases of fish management.

The necessary research, conducted by trained personnel, must range from detailed physiological studies on individual fishes to broad-scale studies of the relationships of populations and environmental conditions.

Constructive programs of research should be developed by universities and by administrative units--State, Provincial, or Federal--to make the most advantageous

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A revision of the North American Fish Policy which was adopted by the Society in 1938 and published in the Transactions of the American Fisheries Society, volume 68 (1938), pages 40-51.

use of available facilities and personnel. The comprehensive programs made possible through such coordination of resources should encompass the necessary fundamental research in all related fields and the practical problems arising from the application of research findings.

IV. Management. Regulatory laws, stocking, and habitat improvement are the presently recognized tools for management of most sport and commercial fisheries.

Laws for regulation of the catch should be based upon proved need, limited to those necessary for orderly management of fish stocks, and stated as simply as possible. The harvestable surplus of fish should be removed at the most desirable size and in the best condition for sport and food.

Food, game, and forage fishes reared at public expense should be stocked only for public benefit; private fish culture should be encouraged to supply privately owned waters. Only fish free of objectionable diseases and parasites should be used for stocking. Periodic replanting is desirable on lakes that winterkill infrequently or on waters which are occasionally depleted by pollution; otherwise the stocking of the young of any species in waters having adequate spawning conditions is considered of doubtful value. The introduction of exotic species is proper where adequate biological investigation has demonstrated the need and the suitability of the environment, including the possible effects on contiguous waters.

Planting catchable fish in waters where reproduction is lacking and where environmental deficiencies cannot be remedied, is recommended if those who benefit pay the cost of such stocking. Elsewhere public agencies should limit the harvest to the extent that good sport will be maintained by natural spawning. In heavily used waters, fishing for game species must be regarded as a source of recreation, not meat. Private fish culture should be encouraged to provide fish for the table and for those who must have, and will pay for, a full creel.

Habitat improvement includes creation of new fishing waters, control of pollution (including soil erosion), and provision of additional shelter, food, and spawning facilities for fish. Such work should be preceded by a physical and biological survey to determine the factors limiting fish production and the remedies to be applied. The watershed approach is recognized as logical and most efficient.

V. Multiple Use of Waters. Fishery resources are too important to be disregarded in any water-development project. Throughout most of North America the scarcity of water precludes any single-purpose development. Any plan to use water for power, irrigation, navigation, or mining, or to carry waste products should include maintenance of the fisheries as a co-equal objective and become part of the project cost.

Wherever an agency plans any development that will impair either the quantity or the quality of water available for fish life, mitigation of fish losses should be the financial responsibility of the sponsoring agency. Local projects are State or Provincial responsibilities. Interstate problems should be solved by interstate compacts.

The Federal agencies concerned with fisheries and public health should be responsible for conducting research in cooperation with the States and Provinces on the effects of pollution and other water uses and on methods for preventing loss of fish. State and Provincial agencies should conduct research on purely local problems.

VI. Adoption of Uniform Common and Scientific Names of Fishes. The standing committee of the Society should accelerate its efforts to have the most appropriate common names accepted by fishery administrators and the general public.

VII. Education and Publicity. Progress in the management of fisheries is dependent upon the public understanding and acceptance of current and proposed

programs. Every available means should be employed to disseminate factual information in a form that will be readily understood and accepted.

North American Fish Policy Committee

Richard S. Croker W. J. K. Harkness
John F. DeQuine A. V. Tunison
Albert S. Hazzard, Chairman

Adopted by the Society, September 14, 1954.

REVIEW

FERTILIZERS IN FISHPONDS

C. H. Mortimer; with additional material and a foreword, C. F. Hickling
Colonial Office Fisheries Publications No. 5 (1954), Her Majesty's Stationery Office, London. 155 pages. 1954. 1 pound 5 shillings.

This very valuable publication may be divided into two main divisions. The former, consisting of 15 sections, summarizes information dealing with pond fertilization, pond muds, liming and use of various inorganic fertilizers, organic manures, and sewage. The latter division--probably the more valuable to most workers--consists of excellent abstracts and references for 351 papers dealing with various aspects of pond fertilization.

Those who are familiar with the literature dealing with this subject will note the omission of a considerable number of papers, and the authors have stated that all Transactions of the American Fishery Society were not available for abstracting. However, the information in this field is well covered, and the review is the most complete that is available on pond fertilization.

In the interpretation of results in various countries, the reader should keep in mind that fertilizer requirements should be expected--from what is known in agriculture--to vary with different soils and different crops. Much of the European work on fertilization dealt with the common carp, a species which muddies water to such an extent that inorganic fertilization is relatively ineffective because of reduction of light penetration into pond waters. Changes necessary in fertilization for efficient production of various species of fish under different soil and climatic conditions await more intensive studies.

This review and bibliography should be read by all who are working on pond fertilization and should stimulate additional works on the various problems involved.

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With each year class of lake trout produced experimentally in a hatchery and marked so it can be recognized in the catch, biologists obligate themselves for at least 8 to 10 years before tedium of getting representative recoveries from the fishery can be eased.

CLEARING HOUSE

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